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SURFACE COMBUSTION.[1]

BY

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MR. PRESIDENT, LADIES AND GENTLEMEN: I count it a high privilege to have been given the opportunity of addressing the members of this world-renowned and venerable Institute upon the new processes of flameless incandescent surface combustion with which my name has become associated, and which, as I hope, will greatly increase the efficiency and widen the range of application of gaseous and liquid fuels in industrial heating operations, especially where high temperatures are required. I believe, also, that this continent, with its courageous industrial enterprise and its magnificent fuel resources of every kind, will afford a splendid field for the practical development of the new methods.

It will economize time and also, I hope, help you better to grasp the subject if, before proceeding to any experimental demonstration, I expound, by the aid of lantern slides, the underlying principles, together with some of the more important results already achieved in the direction of industrial applications of surface combustion. With your kind permission, therefore, I would propose to postpone the principal experi-

[1] Lecture delivered at the Franklin Institute, Philadelphia, October 30, 1911.

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mental demonstration until after the conclusion of the formal part of my discourse.

The problem of the influence of hot surfaces upon gaseous combustion is one which, from a purely scientific stand-point, has engaged my attention for many years past, and, as my recent work has been the direct outcome of earlier scientific investigations, it will be appropriate for me, by way of introduction, to explain briefly the present position of science with respect to this subject.

You will readily understand that a matter which is of great scientific interest as well as of practical utility can hardly be dealt with within the limits of a single lecture. I must necessarily compress my remarks into the smallest possible compass consistent with clearness, omitting many points of secondary interest which otherwise it would have been profitable for me to discuss. I must make many statements, both of fact and of opinion, without advancing any demonstration or proof of them. I can only ask you to accept such statements as coming from one who, having devoted many years to the advancement of the science of combustion, would not willingly mislead you.

It would perhaps help you to an understanding of what is implied by the term "*surface combustion*" if I first of all explain certain facts which differentiate it from the more familiar and perhaps better understood process of combustion as they occur in ordinary flames. In the first place, I would have you understand that all hot surfaces have an accelerating influence upon chemical changes in gaseous systems; a recognition of this fact is of fundamental importance. It may be laid down as a well-established principle that if at any temperature a gaseous system *A* tends to pass over into another system *B*, contact with a solid at the same temperature will accelerate the process.

To take a simple example: If a mixture of hydrogen and oxygen in their combining proportions (electrolytic gas) be maintained in an enclosure with smooth glass walls at a temperature (say) 450° C., there would certainly be a tendency to form steam, but the rate of change would be negligibly small. If, however, there be brought into the system some porous solid material at the same temperature, so that a large surface is exposed to the gases, the rate of change would at once be rapidly accelerated in the layer of gas immediately in contact with the

hot surface. Steam, the product, would diffuse outwards from the surface, and the supplies of hydrogen and oxygen at the surface would be renewed by diffusion inwards. Thus combustion would proceed heterogeneously at the surface until the transformation of the original electrolytic gas into steam was complete. In the case just cited, the rate of combustion, although now quite measurable, would probably be insufficient to cause any self-heating of the enclosure. The temperature would remain at 450° C., which is well below either the ignition temperature of the combustible mixture or the point at which a solid would attain even incipient incandescence.

It is therefore necessary to distinguish between two possible conditions under which gaseous combustion may occur, namely: (1) *Homogeneously*—that is to say, equally throughout the system as a whole, at temperatures *below* the ignition point *slowly and without flame*, and at temperatures *above* the ignition point *rapidly and with flame*, and (2) *heterogeneously*, or only in layers immediately in contact with an incandescent surface ("surface combustion"). It is also necessary to remember that, *ceteris paribus*, the heterogeneous surface to combustion is a faster process than the normal homogeneous combustion of ordinary flames.

It has long been recognized as a scientific anomaly that metals of the platinum group have power of inducing gaseous combustion, more particularly that of hydrogen, but it has hitherto been generally considered that in industrial heating operations contact of all flame with surface should be avoided. Indeed, it was a favorite dictum of Frederick Siemens, who was the first to impress upon technologists the importance of radiation in furnace operations, that hot surfaces by promoting dissociation must necessarily hinder combustion. And, in view of the great influence which Siemens exercised on contemporary thought, it is perhaps hardly to be wondered that technologists have hitherto never realized the possibilities of surface combustion in the field of industrial heating operations. I am convinced, however, that Siemens was wrong in his judgment concerning this matter.

It may be profitable for us to consider for a moment how far it is possible to accelerate the process of combustion in ordinary flames. We are apt to think of ordinary flame combustion

as an instantaneous process, whereas, when considered in terms of what I may call "molecular time," it is certainly a very slow transaction. Thus, for example, when electrolytic gas is ignited by a spark near the closed end of a tube, the flame is initially propagated by conduction with a uniform slow velocity of 20 metres per second, and during this preliminary period of "*inflammation*," as it is sometimes termed, the total duration of chemical change in each successive layer of gas is of something like the order of one-fiftieth part of a second. But this is at least one hundred million times as long as the average interval between successive molecular collisions in electrolytic gas at the ordinary temperature. The conditions prevailing during the initial period of "*inflammation*" in a gaseous explosion correspond to those in ordinary flames, and it is at once apparent how very slow is the actual chemical change when viewed from the stand-point of molecular time.

But after the flame has travelled a short distance along the tube it is rapidly accelerated, under the influence of compression waves reflected from the closed end of the tube, until a new condition, known as "detonation," is set up. In "*detonation*" the flame is propagated through the mixture by adiabatic compression at an enormously great and constant velocity, amounting in the case of electrolytic gas at atmospheric pressure to no less than 2,820 metres, or about 1¾ miles per second. The combustion now proceeds under conditions of maximum intensity, both as regards the actual duration of chemical change and the temperatures produced in each layer of the burning gases. Some years ago, in conjunction with Dr. Bevan Lean, I found that the duration of chemical action in each successive layer of electrolytic gas in which "*detonation*" has been determined does not exceed one five-thousandth or possibly one ten-thousandth part of a second, and for the same mixture Mr. D. L. Chapman, of Oxford, has calculated that the temperature attained in the explosion wave is 4265° C. Therefore it may be inferred that whilst in "detonation" the duration of chemical change in each successive layer of electrolytic gas is probably about a hundred times shorter than in the preliminary period of "inflammation," it still remains at least a million times as long as the average interval between successive collisions in the mixture at the moment of its being fired.

In order to give you visual evidence of the validity of this conclusion, I will throw on the screen a photograph taken by Professor Harold B. Dixon, of Manchester, of the progress of an explosion in electrolytic gas from its origin at a point a few inches from the closed end of a horizontal glass tube up to the attainment of its maximum force and intensity in detonation (Fig. 1). The flame was photographed on a highly sensitive film moving vertically at a velocity of about 50 metres per second, and the graph thus traced on the film was, therefore, compounded of the horizontal velocity of the flame along the tube and the vertical velocity of the film. The black line on the photograph is due to a reference mark made by gumming a strip of black paper on the tube at a distance of one metre from its closed end. You will observe that the flame was initially propa-

FIG. 1.

gated through the explosive mixture with a comparatively slow, uniform velocity. Its luminosity during this initial period of "*inflammation*" (which corresponds to the conditions of ordinary flames) was comparatively feeble, and from the slope of the graph it is evident that its velocity was much slower than that of the vertical motion of the film. After traversing about 0.5 metre along the tube, its velocity was accelerated, and simultaneously the intensity of the combustion increased, as is indicated in the photograph by a brightening of the flame. The acceleration of the flame continued until, at a point just beyond the reference mark, "*detonation*" was set up. At this juncture the flame suddenly increased in brilliance and dashed forward through the mixture at a velocity many times greater (as a matter of fact, more than 50 times) than the vertical velocity of the film; at the same time a strongly luminous wave of compres-

sion (called the "*retonation wave*") was sent backwards through the still burning gases. The luminous track of this retonation wave is to be ascribed to its accelerating influence upon the residual combustion in a mixture which had already been "inflamed," and it is evident from the photograph that this after-burning continued even after the "retonation wave" had been reflected back again from the closed end of the tube. Whilst this photograph has no *direct* bearing upon the question of surface combustion, it nevertheless proves beyond all question that the conditions prevailing in ordinary flames are such as admit of a great acceleration of the combustion, and it will, I hope, help you to understand what I shall subsequently refer to as the intensifying action of an incandescent surface upon gaseous combustion.

The influence of hot surfaces upon combustion at low temperatures seems to have occupied the attention of several chemists (Dulong and Thenard and, independently, Dobereiner in France, Sir Humphry Davy, William Henry, Thomas Graham, Faraday, and De la Rive in England) during the first third of the last century, but not one of these distinguished men succeeded in evolving a satisfactory theory of the phenomenon, nor, with the exception of the famous "Dobereiner lamp," was there any practical outcome of their efforts. In 1836, after a long but abortive controversy between Faraday and De la Rive, interest in the subject dropped, and was not revived again until recent years. My attention was first drawn to the subject during the course of an investigation on the mechanism of hydrocarbon combustion at low temperature, which I was then engaged upon in conjunction with R. V. Wheeler and others of my pupils at the Owens College, Manchester (now the Manchester University). The subject soon became so absorbently attractive that we embarked upon what proved to be a long but fruitful inquiry into the influence of a great variety of hot surfaces upon the combination of hydrogen and oxygen at temperatures below the ignition point. The inquiry has also included other cases of slow combustion, and I am hoping that experiments which are now being carried out by Mr. Harold Hartley in my laboratory at Leeds University will enable us to advance materially the science of the subject.

It would, however, be premature for me to attempt any prediction of our final conclusions, because several points remain

to be cleared up, but I may safely say that our experimental results justify the conclusion that the power of accelerating gaseous combustion is possessed by *all* surfaces at temperatures below the ignition point in varying degrees, dependent upon their chemical characters and physical texture. Moreover, the "activity" of a given surface can be enhanced or diminished at will by previous special treatment in a truly marvellous manner; thus, for example, in the case of the combination either of hydrogen or of carbon monoxide with oxygen at low temperatures in contact with a non-oxidizable metal or non-reducible oxide, the "activity" of the surface may be greatly stimulated by previous contact with oxygen. Again, there is abundant evidence that the actual surface combustion is dependent upon a prior "absorption" (or condensation) of the combustible gas and (possibly, also) of the oxygen by the surface (although to what extent the oxygen is involved is not as yet perfectly clear). The "absorbed" (or condensed) gas becomes "activated" (probably "ionized," as the physicists would call it) by association with the surface. Finally, certain important differences have been established between ordinary homogeneous combustion and heterogeneous "surface combustion;" thus, for example, whereas the presence of water vapor certainly accelerates, if it is not essential to, the homogeneous combustion of carbon monoxide, it greatly retards its heterogeneous combustion in contact with a surface such as fire-clay; or, again, whereas methane has a much greater affinity for oxygen than either hydrogen or carbon monoxide in ordinary flames, a hot surface, by virtue of some "selective" action, will completely reverse the usual order of things—a remarkable circumstance, than which no better proof could be afforded of the reality of surface combustion.

My next contention, and one which leads right up to the main theme of my discourse, is that if hot solids possess the power of accelerating gaseous combustion at temperatures in the neighborhood of the ignition point, the same power must also be manifested at higher temperatures, and especially so when the surface itself becomes incandescent. Indeed, my belief is that not only does the accelerating influence of the surface upon combustion rapidly increase with the temperature, but also that the difference between the powers of various surfaces (which at low temperatures are often considerable) diminishes with ascending temperatures, until at bright incandescence they practically dis-

appear. If, therefore, an explosive gaseous mixture is either injected on to or forced through the interstices of a porous refractory incandescent solid under certain conditions, which will be hereafter explained, a greatly-accelerated combustion takes place within the interstices or pores, or, in other words, within the boundary layers between the gaseous and solid phases, wherever these may be in contact, and the heat developed by this intensified combustion maintains the surface in a state of incandescence *without any development of flame*. Such conditions realize my conception of "*flameless incandescent surface combustion*" as a means of greatly increasing the general efficiency of industrial heating operations wherever it can be conveniently applied.

There are two further points which I particularly wish to make clear to you. In dealing with gaseous interactions at high temperatures it is necessary to think in terms of what I may call "molecular" dimensions. Our ordinary units of time, space, and mass are altogether too gross and must be discarded if we would wish to form a true mental picture of the mechanism of combustion; when, therefore, I speak of combustion as occurring "*within the interstices or pores*" of an incandescent solid, it must be understood that I mean "porosity" in a molecular sense. A solid may appear to the eye to be dense, and yet be highly permeable to the molecules of a gas; from this point of view it is only vitreous surfaces such as glass which are (relatively speaking) non-porous to gases, and even glass when it becomes devitrified is sufficiently porous to induce a slow surface combustion.

In the second place, I want to emphasize the fact that the incandescent solid plays a specific rôle in this surface combustion; it is no mere idle "looker-on" at the surging crowd of reacting molecules which swarm around it. On the contrary, it so galvanizes and incites the dormant affinities between the combustible gas and oxygen that the stately minuet of ordinary flame combustion gives place to the wild intoxication of the Venusberg. The manner in which the surface acts is still, perhaps, a matter of conjecture, but the fact that it so acts can no longer be disputed. In a discussion which took place at the British Association in 1910, Sir J. J. Thomson insisted that combustion is concerned not only with atoms and molecules, but also with

electrons—*i.e.*, bodies of much smaller dimensions and moving with very high velocities—and suggested that "in reference to the influence of hot surfaces in promoting combustion, to which Professor Bone had drawn attention, it was not improbable that the emission of charged particles from the surface was a factor of primary importance." Those of you who may have followed recent developments of the corpuscular views of electrical action will remember how it has been proved experimentally that incandescent surfaces emit enormous streams of electrons travelling with high velocities, and the actions of these surfaces in promoting combustion may ultimately be found to depend on the fact that they bring about the formation of layers of electrified gas in which chemical changes proceed with extraordinarily high velocity.

THE NEW PROCESSES OF INCANDESCENT SURFACE COMBUSTION.

Leaving now the theoretical aspects of the subject, I will, with your kind permission, proceed to describe, and in some cases to illustrate by experiment also, some of the more important features of the two processes of "incandescent combustion" recently evolved by Mr. C. D. McCourt and myself at the works of Messrs. Wilsons & Mathiesons, Ltd., of Leeds, where our experimental station is located. The experiments which I hope to show you during the demonstration after the conclusion of my lecture were originally designed for lectures which I had the honor of giving at the Royal Institution of Great Britain about six months ago, and were subsequently repeated at the recent Glasgow meeting of the British Institution of Gas Engineers. They are intended to convey to an audience of technical men a general idea of the wide field of practical utility which we believe lies before the new system; they are necessarily on a small scale, and in nearly all cases the apparatus is merely of a "demonstration" order in which the rapid illustration of some striking effect is the main consideration.

(*a*) GENERAL CHARACTER AND ADVANTAGES CLAIMED.

The distinguishing and essential feature of the new processes is that a homogeneous explosive mixture of gas and air, in the proper proportions for complete combustion (or with air in slight

excess thereof), is caused to burn without flame in contact with a granular incandescent solid, whereby a large proportion of the potential energy of the gas is immediately converted into radiant form. The advantages claimed for the new system are: (1) The combustion is greatly accelerated by the incandescent surface, and, if so desired, may be concentrated just where the heat is required; (2) the combustion is perfect with a minimum excess of air; (3) the attainment of very high temperatures is possible without the aid of elaborate "regenerative" devices; and (4), owing to the large amount of radiant energy developed, transmission of heat from the seat of combustion to the object to be heated is very rapid. These advantages are, as I believe, so uniquely combined in the new system that the resultant heating effect is, for many important purposes, not only pre-eminently economical but also easy of control.

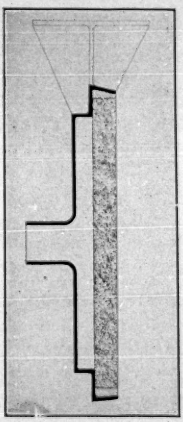
(*b*) DIAPHRAGM HEATING AND ITS APPLICATIONS.

In the first process the homogeneous mixture of gas and air is allowed to flow under slight pressure through a porous diaphragm of refractory material from a suitable feeding chamber behind (see Fig. 2) and caused to burn without flame at the surface of exit, which is thereby maintained in a state of red-hot incandescence. The diaphragm is composed of granules of firebrick bound together into a coherent block by suitable means; the porosity of the diaphragm is graded to suit the particular kind of gas for which it is to be used, but for coal gas, or carburetted water gas,[2] a diaphragm so porous that the gaseous mixture will readily flow through it at a pressure of $\frac{1}{8}$" water gauge is employed. [At this point such a diaphragm was exhibited.] The diaphragm is mounted in a suitable casing, the space enclosed between the back of the casing and the diaphragm constituting a convenient feeding chamber for the gaseous mixture which is introduced at the back. Such a mixture may be

[2] NOTE.—In England the public supply of illuminating gas is usually entirely or mainly composed of undiluted coal gas, whereas you in America are (I am told) usually supplied with a mixture of carburetted water gas with a small proportion of coal gas. The diaphragm process works equally well with both kinds of gas, or, indeed, with gas of any intermediate composition.

obtained in either of two ways, namely, (1) by means of suitable connections through a Y piece with separate supplies of low pressure gas and air (2 or 3 inches w. g. only is sufficient), or (2) by means of an "injector" arrangement connected with a supply of gas at 2 pounds per square inch pressure; the gas in this case draws in its own air from the atmosphere in sufficient quantity for complete combustion, the proportions of gas and air being easily regulated by a simple device. To start up a diaphragm, gas is first of all turned on and ignited as it issues at the surface, then air is gradually added until a fully aërated

FIG. 2.



mixture is obtained. The flame soon becomes non-luminous and diminishes in size; then, a moment later, it retreats on to the surface of the diaphragm, which at once assumes a bluish appearance; soon, however, the granules at the surface attain an incipient red heat, producing a curious mottled effect; finally, the whole of the surface layer of granules becomes red-hot, and an accelerated "surface combustion" comes into play. All signs of flame disappear, and there remains an intensely glowing surface—a veritable wall of fire, but without flame—throwing out a genial radiant heat, which can be steadily maintained for as long as required. My assistant will now start up one of the

diaphragms (area 1 square foot) on the table, and you can judge for yourselves both of the quickness of the operation (it takes but a minute or two after starting up to attain full red heat) and of the beauty of the radiant effect produced. No one, I imagine, can see one of those diaphragms in operation and remain a disbeliever in the fact and potency of "surface combustion." Whilst the diaphragm is in operation before you, I may point out some of the more striking features of the phenomenon which it presents. In the first place, the actual combustion is confined within a very thin layer (⅛ inch to ¼ inch only) immediately below the surface, and no heat is developed in any other part of the apparatus. Kindly observe that, whilst the front of the diaphragm is intensely hot, the back of the apparatus is quite cold; in fact, so cold that I can lay my hand on it. Secondly, the combustion of the gas, although confined within such narrow limits, is perfect, for when once the relative proportions of gas and air have been properly adjusted no trace of unburnt gas ever escapes from the surface. Thirdly, the temperature at the surface of the diaphragm can be instantly varied at will by altering the rate of feeding of the gaseous mixture; there is no lag in the temperature response—a circumstance of great importance in operations where a fine regulation of heat is required.

The temperature of a diaphragm working on a coal gas and air mixture, at a given rate of feeding, depends on whether or not the intense radiation from its surface is impeded; with a freely radiating surface, the temperature of a properly-made diaphragm may be maintained at anything up to about 850° C. (say 1550° Fahr.), according to the rate of supply of the combustible mixture. Fourthly, a plane diaphragm such as this may be used in any position—*i.e.*, at any desired angle between the horizontal and vertical planes. Fifthly, the diaphragm method is amenable to a variety of combustible gases.

Coal or coke-oven gas (either undiluted or admixed with water gas), natural gas, petrol-air gas, carburetted water gas are all well suited in cases where unimpeded radiation is required.[3]

[3] NOTE.—Experiments carried out in England during my absence in America have proved that diaphragms may be successfully worked with "Mond gas," a circumstance which considerably enlarges the field of industrial application of the diaphragm process.

We have constructed and successfully operated plane diaphragms of all sizes up to 4 square feet in area (2 feet by 2 feet) and are able to vouch from experience that their durability and radiant power are unimpaired even after long-continued use.

INCANDESCENCE NOT DEPENDENT ON EXTERNAL ATMOSPHERE.

A further important point to which I wish to direct your attention with regard to diaphragm heating is the fact that the incandescence of the surface in no way depends upon the external atmosphere. When once the diaphragm has become incandescent, and the proportions of air and gas supplied in the mixing chamber at the back have been properly adjusted, the surface will maintain its incandescence unimpaired, even in an atmosphere of carbon dioxide.

In order to demonstrate to you this point, we have here a chamber with a glass front which has been filled with carbon dioxide. This lighted taper is, you will observe, at once extinguished when plunged into the chamber. My assistant will now plunge into the chamber a small diaphragm which is in a state of brilliant incandescence. [The diaphragm was plunged into the chamber.] You will observe that, although the surface is now surrounded by an atmosphere of carbon dioxide, its incandescence is unaffected.

APPLICATIONS OF DIAPHRAGM HEATING.

I need hardly point out to you the many obvious purposes to which "diaphragm heating" may be applied. Grilling, roasting, toasting are at once suggested; others will doubtless occur to you—such efficient means of attaining radiant heat can hardly fail to find new industrial uses. It will suffice if I demonstrate to you one which has perhaps the charm of novelty, namely, the evaporation and concentration of liquids by means of radiant energy emitted from a diaphragm fixed in a horizontal plane above the surface of the liquid. By means of this diaphragm mounted so that its incandescent surface is directed downwards, we will now evaporate in this dish a solution of sodium silicate (water glass), an operation it would be impossible to carry out satisfactorily by the ordinary means of heating the vessel by flame from below. By the new method, however, only the top-

most layers of the liquid are heated; the radiant energy of the diaphragm is instantly transmitted to the surface of the liquid, where it is as instantly absorbed and utilized for the evaporation. The sodium silicate separates out as a skin on the surface of the liquid; it is then dried by the radiant heat, and at intervals the crust of dry sodium silicate may be skimmed off. In this way we are not only able to evaporate the solution with a great economy of heat, but we are also able to complete the evaporation of highly concentrated solutions much more easily than by means of heat applied from below.

INCANDESCENT SURFACE COMBUSTION IN A BED OF REFRACTORY GRANULAR MATERIAL.

The second process is applicable to all kinds of gaseous or vaporized fuels, and can be adapted to a great variety of both small- and large-scale industrial heating operations. It consists essentially in injecting, through a suitable orifice, at a speed greater than the velocity of back-firing, an explosive mixture of gas (or vapor) and air in their combining proportions into a bed of incandescent granular refractory material which is disposed around or in proximity to the body to be heated.

I can perhaps best describe the process by the aid of two diagrams showing its applications to the heating of crucible and muffle furnaces. The first slide on the screen (Fig. 3) shows the process as applied to a crucible furnace. The crucible is surrounded by a bed of highly refractory granular material. The mixture of gas and air is injected at a high velocity through a narrow orifice in the base of the furnace, and as it impinges upon the incandescent bed combustion is instantaneously completed without flame.

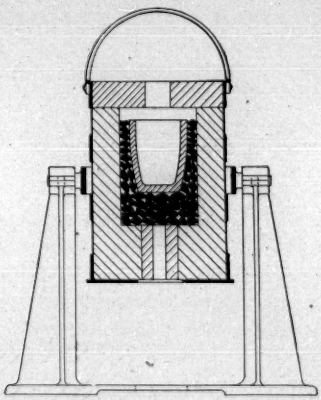
The seat of this active surface combustion is in the lowest part of the bed; the burnt gases, rising through the upper layers, rapidly impart their heat to the bed, maintaining it in a high degree of incandescence. The next slide (Fig. 4) shows a similar arrangement for the heating of a muffle furnace, an arrangement which needs no further explanation.

It is obvious that the process is adaptable to many other furnace operations, as, for example, to the heating of retorts, annealing furnaces, and the like. Moreover, it is not essential

that the bed of refractory material shall be disposed around the vessel or chamber to be heated; it may be equally well packed into tubes or the like, traversing the substance or medium to be heated. This latter modification is, as we shall see later, important in relation to the melting of metals or alloys, and also in relation to steam raising in multi-tubular boilers.

By this process much higher temperatures are attainable with a given gas than by the ordinary methods of flame combustion without a regenerative system, and, as a matter of fact, we have found that with any gas of high calorific intensity (such as coal

FIG. 3.



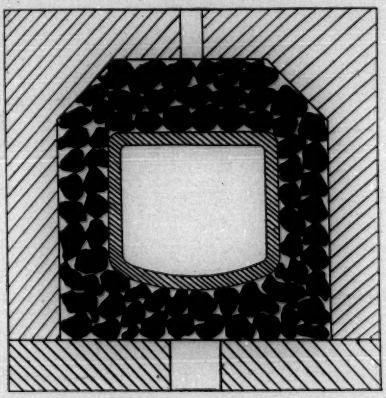
gas, water gas, or natural gas) the upper practicable temperature limit is determined by the refractoriness of the material composing the chamber to be heated—*i.e.*, the muffle or crucible—rather than by the possibilities of the actual combustion itself. When I tell you that in a crucible fired by coal gas on our system we have melted "Seger-cone" No. 39, which, according to the latest determination of the Reichsanstahlt in Berlin, melts at 1880° C., and also that we can easily melt platinum, you will appreciate the possibilities of the method in regard to high temperatures with gas-fired furnaces.

Indeed, at one stage of the investigation, we had considerable difficulty in obtaining materials for the construction of

muffles and crucibles which would stand the high temperatures obtainable with coal gas, but we have now succeeded in constructing muffles which will stand temperatures up to 1400° or 1500° C. It is obvious that the bed of incandescent granular material must be composed of a substance which will not at the working temperature exercise a fluxing action upon the walls of the crucible muffle or walls of the furnace.

For the very high temperatures obtainable with coal gas, water gas, or natural gas we employ a bed composed either of fragments of magnesia, which has been burned at a high tem-

FIG. 4.



perature, or of a highly refractory neutral material specially prepared for us. In cases where temperatures required do not exceed 1200° C. the bed of refractory material may be composed of a good quality of firebrick crushed and meshed to a suitable size.

To start up a furnace, gas is first of all turned on and lighted as it issues from the top of the furnace; the air supply is then gradually opened until the flame strikes back through the granular material and is arrested at the orifices in the base of the furnace through which the explosive mixture enters. The flame quickly raises the granular material in the neighborhood of these orifices to a state of incandescence, and "surface combustion" quickly supersedes the flame. As soon as the lower

regions of the bed have become thoroughly incandescent, the rate at which the mixture is being fed into the furnace may be materially increased, so that very quickly the whole of the lower region of the incandescent bed becomes the seat of the intensive surface combustion.

As I have already stated, the method is applicable to all kinds of gaseous and vaporous fuels, but naturally the maximum temperature obtainable in any given case will depend upon the volume and heat capacity of the products for a given heat development in the bed.

Thus, whilst with actual coal gas, water gas, or natural gas, it is possible to attain temperatures of up to at least 2000° C., with a producer gas, such as Mond gas, about 1500° C. would probably be the maximum temperature obtainable without regeneration. With some degree of regeneration, which in most cases would be quite practicable, these limits could be considerably exceeded.

In order to give you some idea of the heating efficiency of this process, I have drawn up in tabular form on the next slide (Fig. 5) the results of a test on a muffle furnace in which a muffle 9½ inches long by 5¼ inches wide by 3¼ inches high was heated to temperatures between 815° and 1425° C. with a fully aërated coal gas of 540 B.Th.Us. (net) per cubic foot.

The condition under which the test was carried out made possible the accurate determination of the rate of gas consumption requisite to maintain the muffle at any constant temperature between 815° and 1425° C.

FIG. 5.

RESULTS OF THE TESTS WITH A MUFFLE FURNACE USING COAL GAS OF NET CALORIFIC VALUE 540 B.TH.US. PER CUB. FT. AT 15° C. AND 760 M.M.

Dimensions of Muffle 9½" x 5¼" x 3¼".

Temp. in middle of Muffle.		Gas consumption to maintain temp. constant Cub. Ft. per hour at 15°C. *	Temp. of Products.	
Cent.	Fahr.		Cent.	Fahr.
815°	1499°	21.0	540°	1004°
1004°	1840°	35.5	645°	1193°
1205°	2201°	58.0	870°	1598°
1424°	2596°	79.0	1085°	1985°

*These consumptions refer to Leeds coal gas of net calorific value 540 B.Th.U. per cubic foot at 15°C. and 760 m.m.; for carburetted water gas of higher calorific value, such as is supplied in many American cities, the consumptions for corresponding temperatures would, of course, be somewhat less than these figures.

The temperatures given in the first two columns are those recorded by a thermo-junction placed in the middle of the muffle. The temperature of the escaping products was also ascertained by means of a standard thermo-junction. I particularly want you to observe that the temperature of the products is in every case 300° to 350° C. lower than that of the muffle, and that even with a muffle temperature of 1424° C. there was no appearance of flame whatever at the top of the furnace. The gas consumptions recorded in the middle column are extremely economical in comparison with those required for ordinary heating by flame contact. Thus, for example, in a similar test with a muffle of the same size heated by flame contact in a furnace of modern design, the gas consumption to maintain the muffle at 1055° C. (which was the maximum temperature obtainable) was 105 cubic feet per hour, whereas by interpolation from the above numbers the consumption on the "surface combustion" furnace at the same temperature would have been about 43 cubic feet per hour only.

SURFACE COMBUSTION AS APPLIED TO STEAM RAISING IN MULTI-TUBULAR BOILERS.

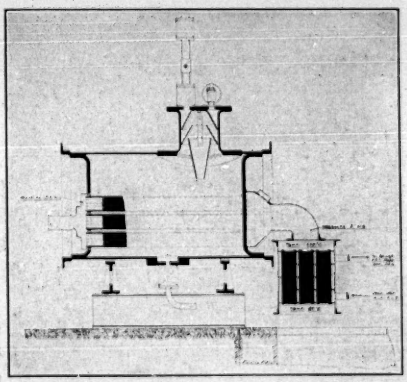
I now come to a very important application of our process to the raising of steam in multi-tubular boilers, and to the melting of metals and alloys. I will, first of all, take the subject of steam raising, and by the aid of lantern slides I will endeavor to explain to you the construction and performances of a new type of gas-fired boiler in which the principle of surface combustion is utilized.

The diagram on the screen (Fig. 6) represents an ordinary multi-tubular boiler of cylindrical section. It is traversed horizontally by a series of steel tubes, each 3 feet only in length and 3 inches in internal diameter. These tubes are packed throughout their whole length with fragments of a suitable refractory material, meshed to a proper size. Into the front end of the tube, where the gaseous mixture is introduced, is fitted a fire-clay plug, through which is bored a circular hole of about ¾-inch diameter. This plug serves a double purpose of keeping the front end of the boiler cool and of providing a suitable aperture through which the gaseous mixture may be introduced at a speed very much higher than the speed of back-firing.

Attached to the front plate of the boiler is a mixing cham-

ber of special design (not shown in detail on the diagram). The mixture fed into the boiler tubes from this chamber consists of the combustible gas with a proportion of air very slightly in excess of that required for complete combustion. The mixture is injected or drawn in (either by pressure or by suction) through the orifice in this fire-clay plug onto the incandescent material in the tubes. The combustion of the mixture in contact with the incandescent material is completed before it has traversed a length of about 6 inches from the point of entry to the tube. The result is that the core of the material at this part

FIG. 6.



of the tube is maintained at a high temperature, although the loci of actual contact between the hot material and the walls of the tube are so rapidly cooled by the transmission of heat to the water in the boiler that they never attain a temperature anything even approaching red heat.

The combustion having been completed, the remainder of the material acts as a baffle toward the burnt gases as they traverse the tubes at a high velocity, causing them to impinge repeatedly on the walls of the tubes. The usual rate at which the gaseous mixture is fed into the boiler corresponds to an hourly consumption of about 100 cubic feet of coal gas *plus* six times its volume of air for every tube of the boiler, or an equivalent volume—*i.e.*, equivalent as regards heating capacity—of any

other gaseous mixture. Thus in the case of a ten-tube boiler, on which our original experiments were made, the consumption of coal gas was about 1,000 cubic feet per hour *plus* about 5,500 or 6,000 cubic feet of air. This will convey an idea of the extremely rapid rate at which the mixture is caused to traverse the tubes.

After the burnt products have traversed the boiler tubes, and at their point of exit therefrom, it is found that their temperature is never more than about 70° C. above that of the water in the boiler, which, of course, depends upon the pressure at which the steam is being generated; this is obviously a much

FIG. 7.

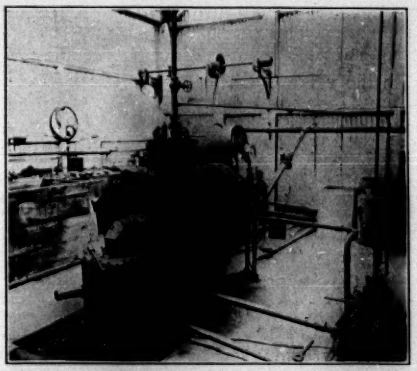
lower temperature than that at which the products of combustion usually pass away from a multi-tubular boiler. But in order to increase still further the efficiency of steam-raising the products are passed through a short tubular feed-water heater constructed on the same principle as the boiler.

THE TEN-TUBE EXPERIMENTAL BOILER.

I will now briefly describe, by the aid of photographs (Fig. 7) and slides, the construction and performance of a ten-tube boiler on which we have been experimenting for upwards of a year in Leeds. The connections to the front of the boiler (Fig. 7) consist essentially of a tube for the supply of gas and another

for the supply of air. The gas and air are mixed before entering the feeding chamber, which is attached to the front plate of the boiler; the gaseous mixture is burned in the tubes of the boiler; the products pass outwards at the other end into a small chamber, and from thence into the feed-water heater. The latter contains nine tubes, each 1 foot in length and 3 inches diameter, which are filled with granular material to effect the exchange of heat. The second view of the boiler (Fig. 8) shows the end at which the burnt gases make their exit.

FIG. 8.



RESULTS OBTAINED WITH THE BOILER.

With regard to the results achieved with this boiler, in our experimental station at Armley, there is no coke-oven gas or producer gas available, and therefore we have worked entirely on Leeds coal gas. But there is no doubt that had we been able to use the surplus gas from by-products coke ovens (which has practically the same composition and calorific value as Leeds coal gas) we should have obtained the same efficiency as with the Leeds gas. The mixture of gas and air was passed into the feed chamber of the boiler at a pressure of 17.3 inches water gauge. This pressure is necessary in order to overcome the resistance of the packing of the tubes to the passage of the gases through them. The pressure of the products entering the tubes

of the feed-water heater was 2 inches water gauge. In carrying out the test, the water was evaporated at a pressure of 100 pounds per square inch above that of the atmosphere. The temperature of the boiling water was therefore 168° C. (or 337 Fahr.). The temperature of the combustion products leaving the boiler tubes was 230° C. The average temperature of the products leaving the feed-water heater was 95° C. (or 203° Fahr.). The temperature of the water entering the feed-water heater was 5.5° C. (or 42° Fahr.), and it was heated to 58° C. (or 136.4° Fahr.) before entering the boiler—entirely at the expense of the burnt gases.

Let us now consider the heat-balance of the boiler during the test. The amount of coal gas fed into the boiler, expressed as dry gas at 0° C. and 760 mm., was 996 cubic feet per hour. The *net* calorific value of the gas was 562 B.Th.U. per cubic foot, so that the total heat supplied to the boiler in terms of the *net* calorific value of the gas was 559,800 B.Th.U. per hour.

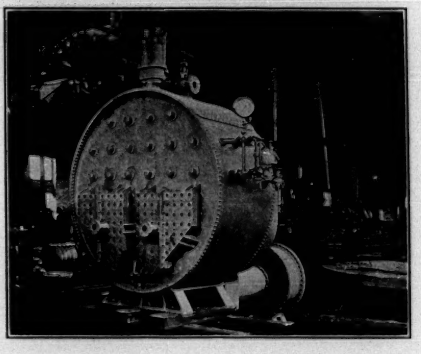
As to the amount of water evaporated, the following figures apply to the combination of the boiler with its feed-water heater, because the two really comprise one steam-raising system. The temperature of the feed-water was 5.5° C., and the steam was being raised at a pressure of 100 pounds per square inch above that of the atmosphere. The actual amount of water evaporated was 450.3 pounds per hour, which in terms of water evaporated from and at 100° C. would be 550 pounds per hour. The actual heat therefrom transmitted to the water was $450.3 \times 1172 = 527{,}200$ B.Th.U. per hour. Therefore, the ratio between the heat transmitted to the water and the *net* heat of combustion of the gas burnt was 0.943.

It is one of the outstanding merits of the new system that we are able to burn the gas completely with a minimum excess of free oxygen, and during the test in question the average proportion of carbon dioxide in the combustion products was as much as 10.6 per cent., whilst the oxygen was as low as 1.6 per cent. A most careful examination of the products failed to reveal the presence of even the slightest trace of carbon monoxide, hydrogen, or methane. Therefore, the remainder of the gas was simply nitrogen. Even with as little as 0.5 per cent. of oxygen in the products the combustion of the gas in the tubes is perfect, not a trace of combustible gas escaping.

THE 110-TUBE BOILER FOR COKE-OVEN GAS RECENTLY ERECTED AT THE SKINNINGROVE IRONWORKS IN CLEVELAND, YORKSHIRE.

That the gas-firing of boilers according to the new system has already advanced beyond the merely experimental stage is proved by the recent erection of a 110-tube boiler capable of evaporating not less than 550 pounds of water per hour, to the order of the Skinningrove Iron Company, Ltd. (the Cleveland District, Yorkshire), to be fired by gas from a new installation of Otto-Hilgenstock by-product ovens adjacent to their blast furnaces. I have brought with me slides (Figs. 9 and 10) made

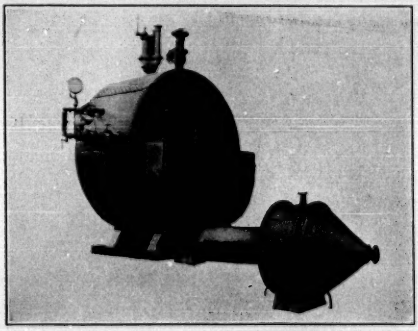
FIG. 9.



from photographs of the builders' boiler with its feed-water heater as erected in the shops of Messrs. Richardsons & Westgarth, Middlesbrough. The boiler itself is a cylindrical drum 10 feet in diameter and only 4 feet from front to back; it is traversed by 110 tubes, each of 3 inches internal diameter, which are packed with fragments of firebrick. The boiler will be worked under the suction of a fan, capable of producing a "suction" of 20 inches water gauge. To the front of the boiler is attached a device whereby gas at 2 inches water gauge pressure from a suitable feeding chamber, together with a proper proportion of air from the outside atmosphere, is drawn (under

the suction of the fan) through a short "mixing tube" into each of the 110 tubes of the boiler, where it is burnt without flame in contact with the incandescent granular material. The products of combustion, having traversed the 4-foot length of packed tube, will pass outwards into a semicircular chamber at the back of the boiler, and thence through a duct to the tubular feed-water heater which is depicted in the second photograph. The fan, which is attached to this feed-water heater, will suck out the cooled products and discharge them through a short duct into the atmosphere outside the boiler house.[4]

FIG. 10.



I have perhaps already said enough about the boiler and its working to convince you that it at least gives promise of combining structural simplicity, high thermal efficiency, and concentration of power in a degree which is absolutely unique. From the constructional point of view nothing could be simpler or more compact than a cylindrical shell only 4 feet long by 10 feet in diameter, supported on a casting and requiring neither elabo-

[4] Since the lecture was delivered, the boiler plant referred to has been successfully started without a hitch, and has been working quite smoothly night and day for upwards of a month. With water of 5° hardness there have been no signs whatever of priming, and the average temperature of the combustion products leaving the feed-water heater has been about 75° C. The plant was taken over and paid for by the Skinningrove Iron Company within a month of its being started up.

rate brick-work setting nor chimney. It has the further structural advantage over all other multi-tubular boilers in that the front plate can never be heated beyond the temperature of the water, however much the firing may be forced, a circumstance which, coupled with the extremely short length of the tubes, implies an absence of strain and greatly reduces the risk of leaky joints. Another feature of the boiler, which makes for efficiency, is the steep "*evaporation gradient*" along the tubes. Under the normal working condition, the "*mean evaporation*" exceeds 20 pounds per square foot of heating surface, or about twice that of a locomotive boiler. Of the total evaporation, no less than 70 per cent. occurs over the first part length of the tubes, 22 per cent. over the next part, and about 8 per cent. over the third part. Such a steep gradient causes a considerable natural circulation of the water in the boiler, a factor of great importance from the point of view of good working. In regard to thermal efficiency, I venture to claim that a boiler unit which, whilst evaporating 20 pounds of water per square foot of heating surface, transmits upwards of 90 per cent. of the net heat of combustion of the gas to the water, and which, if need be, can be forced to a 50 per cent. higher "duty" with only a slight drop in efficiency, stands unrivalled as a steam-raiser. Moreover, in the case of a large boiler of (say) 100 tubes, "elasticity" may be conferred by arranging the tubes in groups, so that they may be either fired up or conversely shut off group by group, successively, in correspondence with variations in the load.

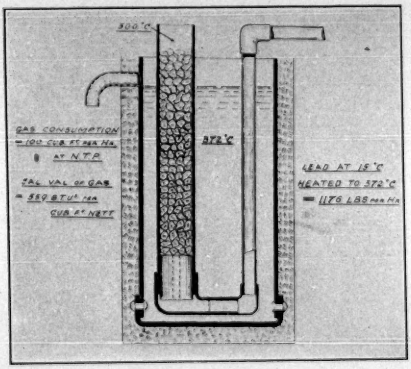
THE MELTING OF EASILY FUSIBLE METALS AND ALLOYS.

It will be readily understood that the principle embodied in the boiler is capable of great extension. Thus, for example: (1) The preliminary concentration of dilute solutions and the heating of liquids generally; (2) the heating of large volumes of air; and (3) the melting of easily fusible metals and alloys.

Unfortunately, time does not permit of my dealing with these further applications in every detail. I should like, however, to refer briefly to the results of our experiments upon the fusion of metals. Our attention was first drawn to this subject by one of the London gas companies, which represented to us that there would be a large field of usefulness for our process in the melt-

ing of type metal for newspaper purposes. The printing of a newspaper of large circulation requires a continuous supply of molten type metal, and we are reliably informed that one of the leading London newspapers requires 20 tons of molten type metal continuously at hand during 16 out of the 24 hours. In the experiments which I now propose to describe to you, lead has been used instead of type metal, but the method is applicable to all metals or alloys whose fusion points lie below about 600 C. The diagram (Fig. 11) on the screen represents an iron tank, efficiently lagged and filled to the top with molten lead at a tem-

FIG. 11.



perature some 50 degrees or thereabouts above its melting point. In the molten bath is fixed an iron tube some 2 or 3 feet in length and of 3 inches internal diameter. This tube is packed (like one of the boiler tubes) with a suitable granular refractory material, and there are suitable arrangements for the introduction of the explosive mixture of gas and air which is to be burned in the tube. When once the device has been started up it will work continuously for days together. Solid lead is continuously fed into the apparatus, and the molten metal is allowed to run over through the spout indicated in the diagram. For the sake of simplicity I have described and illustrated a small tank fitted with one combustion tube, but experiments have been carried out

with tanks holding up to 8 tons or more of molten metal in which a series of combustion tubes are fixed. By means of such an apparatus, lead (or other fusible metals or alloys) may be melted not only very rapidly but with extraordinary efficiency, and as an example of this I will quote the results of a test carried out at our experimental station with a single-tube apparatus. These may be conveniently tabulated as follows:

FIG. 12.

Lead Melting Test.

	Cent.	Fahr.
Temperature of metal charged	15°	60°
Temperature of metal tapped	372°	702°
Temperature of gases leaving apparatus	500°	932°

Lead melted per hour = 1176 lbs.
Gas burnt per hour = 100 cub. ft. at N.T.P.
Net. cal. value of gas = 559 B.Th.U. per cub. ft. at N.T.P.

Heat required to raise 1176 lbs. of lead from 15° C. to 372° C. } = 1176 × 32.67 = 38,420 B.Th.U.

$$\text{Ratio } \frac{38{,}420}{55{,}900} = 0.686$$

Actual "efficiency" of the operation, considering that the bath was maintained at 372° C. } = about 80 per cent. of that theoretically possible.

The conditions of the test were so arranged that the mean temperature of the molten metal in the apparatus (as ascertained by a thermo-junction) was 372° C., throughout the test. Lead ingots, each weighing about 30 pounds, were added at intervals of 1½ minutes; the molten metal displaced was simultaneously run off into moulds. Great care was taken to keep the bath thoroughly molten and at a temperature within a few degrees of the mean value. Burning gas, of net calorific value 559 B.Th.U. per cubic foot, at the rate of 100 cubic feet per hour, it was found possible to raise the temperature of 1176 pounds of lead per hour from 15° to 372° C., the temperature of the products of combustion leaving the tube keeping constant at 500° C., or only 128 degrees above the temperature of the molten metal. From the latest determination by Spring of the specific heat of lead at temperatures up to and above its melting point, and adopting the usually accepted value for the latent heat of

fusion of lead, I calculate that the heat required to raise the temperature of 1 pound of lead from 15° C. to 372° C. (including melting) is 32.67 B.Th.U. Therefore the heat transmitted to the lead per hour during the experiment was $1176 \times 32.67 = 38{,}420$ B.Th.U., whereas the *net* calorific value of the gas burnt per hour was 55,900 B.Th.U., the ratio $\frac{38420}{55900} = 0.686$. Inasmuch, however, as the *net* heat of combustion of the gas is based on the assumption that the products of combustion (less steam) are cooled down to 15° C., whereas in the experiment the temperature of the molten metal was 372° C., it follows that the high ratio of 0.686 does not do full justice to the merits of the system. Under "ideal" conditions, the temperature of the gases leaving the combustion tube could not have been reduced to below 372° C.; it was actually reduced to within 130° of this "ideal" limit. Taking these circumstances into consideration, I calculate that the "efficiency" of the melting operation was practically 80 per cent. of that theoretically possible.

Having now concluded the formal part of my discourse, it remains for me to thank you for the close attention with which you have followed my attempt to deal with the salient features of this new development in scientific technology. After a brief interval, during which my assistant, Mr. Hamilton Davies, will complete his preparations, we will proceed with the experimental demonstration, which, with your kind indulgence, will probably occupy about another hour.

Since this lecture was delivered in Philadelphia a further experiment with the object of determining the maximum temperature obtainable by means of artificial illuminating gas has been tried. An alundum crucible of an extremely high refractory character containing a Seger Cone No. 39 was completely melted down, showing that a temperature approximating 2000° C. had been obtained.

EXPERIMENTAL DEMONSTRATION.

During the demonstration which followed the lecture the following experiments were shown:

(*a*) *Diaphragm Heating.*

(1) Two square diaphragms (each 1 foot x 1 foot), mounted as described in the lecture (see Fig. 2), were lighted up. Gas alone was first turned on and ignited by a taper as it issued from the face of the diaphragm, giving rise to a large, luminous flame. Air was next gradually added; the flame diminished in size, and after a momentary increase in brightness soon became non-luminous. A moment later, it retreated on to the surface of the diaphragm, causing it gradually to glow. As the glow of the surface increased the flame gradually disappeared until finally, when the whole of the surface had attained bright incandescence, it could no longer be detected. The diaphragms were now emitting an intense radiant heat, the influence of which could be felt far into the auditorium. The lecturer pointed out that, although the front of the diaphragm was in a state of bright incandescence, the back of the apparatus was so cold that he could lay his hand upon it; indeed, it felt cold to the touch.

(2) A circular diaphragm, in a state of bright incandescence, was plunged into a chamber full of carbon dioxide, and through which a current of carbon dioxide was uninterruptedly passed. The front of the chamber facing the audience was of glass. It was seen that the incandescence of the diaphragm was in no way diminished on being placed in the chamber, a circumstance due to the fact that sufficient air to completely burn the gas is introduced into the feeding chamber at the back of the diaphragm and also that the flameless combustion at the surface of the diaphragm is instantaneously completed.

(3) The application of the diaphragm principle to the concentration and evaporation of liquids was demonstrated by directing the radiant heat from a diaphragm downwards on to the surface of a solution of sodium silicate contained in a large porcelain basin. The lecturer pointed out how in this way the layers of liquid immediately below the surface only were heated, the main body remaining cold, except for a small amount of heat conveyed to it by conduction. No sooner had the experi-

ment begun than a rapid evaporation in the surface layers of the liquid could be observed. This was succeeded by the formation of a skin of sodium silicate, which was periodically removed by means of a glass rod; the salt separating out at the surface was speedily dried by the radiant heat, and when removed was in the form of a dry, snow-like mass which could be easily powdered by slight pressure in the palm of the hand. The lecturer again reminded his audience that the rapidity and efficiency of this new method of evaporation depended on the fact that the required energy was transmitted from its source to the liquid instantaneously in a radiant form, instead of (as in existing methods) relying chiefly on the infinitely slower transmission by either conduction or convection.

(*b*) *Steam Raising.*

The lecturer explained that it had not been found practicable to carry across the Atlantic the small three-tube experimental boiler (capable of steaming at 100 pounds per square inch pressure) exhibited at the Royal Institution of Great Britain on April 6th last. In substitution, he had brought over with him a single tube, 3 feet in length and 3 inches in internal diameter, suitably mounted on a trough of water which was open to the atmosphere. The tube was fitted with a fire-clay plug, and packed with suitable refractory granular material, exactly as in the case of the boiler tubes. He would now fire up the tube with a mixture of gas and air on the new principle explained in the lecture, and would afterwards invite the audience to file past the trough in order that each person might judge for himself of the extraordinary efficiency and rapidity of the evaporation. A centigrade thermometer would be placed with its bulb in the end of the tube from which the burnt gases made their exit, and the lecturer predicted that the temperature would now rise beyond about 210°, when gas at the rate of 100 to 120 cubic feet per hour *plus* the air required for complete combustion was being burnt in the tube. (This was subsequently verified.) He would ask the members of the audience to notice how the greater part of the evaporation, actually 70 per cent. of the whole, took place over the first foot of the tube, a circumstance which produced a vigorous natural circulation in the boiler.

(c) *The Firing of a Muffle Furnace.*

A furnace carrying a muffle 9¼ inches long x 5¼ inches wide x 3¼ inches high (in side measurements) was next fired up as described in the lecture. As the lecturer explained it would take about thirty minutes for the furnace to attain anything like its full working temperature, which in this case would be about 1400 to 1500° centigrade—a dazzling white heat—he would ask those of the audience who wished to stay until this was attained to note three things, namely: (1) the uniform heating of the muffle chamber, (2) the flamelessness of the combustion, and (3) the comparative coolness of the burnt gases issuing from the two holes at the top of the furnace. Indeed, he would venture to predict that it would be found possible to hold a hand in these products within two or three inches of their issuing from the furnace. (These points were subsequently verified by a number of persons who remained to see the furnace at its full working temperature.)

The Use of Carbon Tetrachloride as a Fire Extinguisher. ANON. (*Revue Scient.*, xlix, 17, 536.)—Carbon tetrachloride is manufactured by passing chlorine over hot carbon bisulphide. A mixture of the vapors of sulphur and of carbon tetrachloride is set free and then condensed. The liquid mixture is treated with sodium hydroxide, which combines with the sulphur to form compounds soluble in water, but leaves the tetrachloride intact. The liquids are allowed to remain at rest, the very dense tetrachloride collects in a lower layer, and the sulphur compounds are decanted. The carbon tetrachloride is an excellent solvent of fatty matters, and has this advantage over the ordinary solvents and over carbon bisulphide, of being absolutely incombustible. Its vapor actually extinguishes fire, and as it is very volatile it is used as a fire extinguisher and has given great satisfaction. It is frequently used in railroad cars. Carbon tetrachloride is colorless, clear, neutral, and has a density of 1.6, and boils at 78° C. Its vapor is a good insulator and is very efficient in extinguishing arcs produced by short circuiting. Thus it is useful in electric installations. It is used as a solvent to extract oil from seeds; in certain cases it is advantageous to mix it with benzine. It is easy to mix the two in such proportions that the mixture is uninflammable at the temperature at which it is to be used, and so that the vapor shall not become explosive in air. At 70° C. a mixture of one-half carbon tetrachloride and one-half benzine is perfectly safe.

Thunderbolts. W. M. THORNTON. (*Phil. Mag.*, xxi, 630.)—The term thunderbolt is generally applied both to the rare phenomenon of ball lightning and to meteoric stones. In the latter case its only meaning is that their luminous path resembles lightning, or that they cause great atmospheric disturbance. Here the term is applied only to ball lightning. The singularity of ball lightning consists in the complete isolation of a gaseous sphere having no envelope, yet within which there is energy stored by previous electrical action, which in the end is liberated with explosive violence. From the few records of its appearance these facts may be considered as established: It is observed as a luminous blue ball, occurring after very intense lightning flashes, either falling slowly from clouds, or moving horizontally some feet above the earth's surface. It is more frequently seen at sea than on land. It appears to move under the action of gravitation on a mass somewhat denser than air, or horizontally in a feeble air current or an electric field of force. The final features are significant: The ball ceases to exist, and an explosion wave travels outwards from the locus it occupied. In all cases a strong smell of ozone follows its disappearance. It is clear there can be nothing present in it but the gases of the atmosphere. All records agree that a thunderbolt is somewhat heavier than air, and the following facts indicate that thunderbolts consist mostly of ozone in active recombination: (1) Ozone is stated to be observed on their dissipation. (2) Ozone is the only gas denser than air produced under electric stress in air, as distinct from streaming spark discharge. (3) On approaching the earth thunderbolts are frequently deflected, and travel horizontally as if repelled. The earth's surface and ozone are both negatively charged in general. (4) The energy liberated on the transition of ozone to oxygen in the volume of the fireball is sufficient to account for the explosive violence of its burst. (5) The blue color usually observed is associated with the sparkless electrical discharge in air which produces ozone. It has been observed that when oxygen and hydrogen combine explosively, in the presence of nitrogen the explosion flame is yellow. Hence the suggestion that the principal constituent of thunderbolts is an aggregation of ozone and partially dissociated oxygen.

Tellurium and Zinc Alloys. M. KOBAYASHI. (*Mem. Coll. Sci. Imp. Univ., Kyoto*, iii, 217)—A thermal and micrographic study showed that tellurium and zinc form the compound TeZn, which consists of dark-red to black crystals, with a melting point of 1238.5°C. and specific gravity 5.54 at 13°C. This compound is miscible with tellurium in the molten condition, and the melting point falls as the proportion of tellurium increases, till it reaches the melting point of pure tellurium, 443.5°C. The compound appears nearly immiscible with zinc when molten.

ELEMENTS OF THEORETICAL AËROMECHANICS.*

Part I—Aerostatics.

BY

A. F. ZAHM, Ph.D.

As some knowledge of the science of equilibrium and motion of fluids is essential to the intelligent study of aëronautics, it seems advisable to present a few of the main principles of that science illustrated by practical applications.

Aëromechanics may be divided into two branches: aërostatics and aërodynamics. Aërostatics is the science of equilibrium of a gaseous fluid; aërodynamics is the science of motion and resistance of such a fluid. The two branches may be treated in succession. We shall begin with aërostatics, or, still better, with the general science of fluid statics.

When a fluid is at rest, or moving with equal velocity at every point, it can offer no resistance to change of shape; that is, it can sustain no shearing force. Its pressure against any surface is, therefore, normal to that surface. From this it easily follows that the pressure at any point of a static[1] fluid is equal in all directions; for otherwise a short filament of fluid at the point, extending in any two directions of unequal pressure, would move in the direction of the lesser pressure, since the filamental wall can exert no tangential restraining force, being assumed frictionless. Hence the term hydrostatic pressure is commonly used for the stress, or force, acting at a point in a material substance, when no tangential or shearing effort is present.

This hydrostatic condition obtains in natural fluids only when they are at rest or moving without change of shape. In perfect or frictionless fluids, which are purely hypothetical, the pressure at every point is hydrostatic, whether the fluid be still or moving without acceleration; but in natural fluids, such as air or water, if there is shearing motion of any kind, there is sure

* Abstracted from the writer's forthcoming popular treatise on aëromechanics.

[1] By static fluid is meant one that is not changing shape or velocity.

to be friction, either superficial or internal. This must be reckoned with, and is duly considered in the kinetics of fluids.

For a long time aëronautical investigators believed that the pressure of a gas or of air against a solid surface is perpendicular, whether the fluid be gliding over the surface or not. But it has been amply proved that when relative motion exists between the surface and fluid there is always surface friction, increasing rapidly with the speed, and hence that the force on the surface cannot be normal.

From the assumption that hydrostatic pressure is normal to a surface follows a second principle, *viz.*: that a pressure applied at any point of a static fluid is transmitted undiminished to all parts of the fluid. For suppose a small, open, cylindrical tube to reach from where the pressure is applied in the fluid to where it is transmitted in any direction taken at random. Since the column of fluid in the tube is at rest, the pressures on its opposite ends must balance, if gravity can be ignored, because they are the only lengthwise forces acting on the column, the wall pressure being exactly normal to the length. Hence the pressure at the two points is equal, and the transmission is perfect.

As an example of the undiminished transmission of pressure, if a loose-fitting cork in a jug full of water be struck inward by a sharp blow of the hand the bottom will break out; if a plug be driven into a cast-iron shell filled with liquid the shell will burst. Again, the water pressure in a faucet is the same as in the far-away reservoir at the same level, if the water is not flowing. So also the pressure of gas or air is constant at all points at the same level in a system of distributing pipes, if the fluid is at rest and at uniform temperature.

The above ignoration of gravity is quite common in engineering, as when computing the pressure of steam in an engine or water in a hydraulic press. But if gravity be taken account of, it is easily seen that the difference of fluid pressure per square unit, at any two levels in the fluid, equals the weight of a vertical column of liquid joining the levels, and of one square unit cross-section.

From the last consideration it follows that a submerged body is buoyed up by a force equal to the weight of the displaced fluid. For the difference of vertical pressure on the ends of any small vertical prism drawn in the body from surface to

surface, at different fluid levels, is the weight of a like prism of the fluid; hence for the whole body the difference of the whole upward and downward components of pressure on its surface is the weight of the fluid displaced. Or, otherwise, suppose the body replaced by frozen fluid. This has the same surface pressure, and its buoyancy evidently equals the weight of the displaced fluid. Whether the body is submerged or buoyed on the fluid surface, the above argument is valid; hence, in general, the buoyancy of a body equals the weight of the displaced fluid. This is Archimedes' principle. Evidently the principle is true for a body immersed in a heterogeneous fluid or in several fluids of different densities.

Since the surface pressures on any immersed body are the same as on a like body of the frozen fluid, whose centre of gravity evidently coincides with the centre of buoyancy, it follows that the centre of buoyancy of any immersed body must be at the centroid[2] of the fluid displaced. The immersed body will, therefore, be in stable, unstable, or neutral equilibrium, according as its centre of mass is below, above, or at the centre of buoyancy. In a common free balloon, for example, in all ordinary positions, the centroid of the entire mass of envelope and load is well below the centre of buoyancy; hence the stability is secure.

In general, a floating balloon is not at rest vertically, but rises or falls. If the balloon has surplus buoyancy and a slack envelope, it may rise, enlarging in bulk till the envelope is fully distended or till the air is so light that its displaced mass does not exceed the mass of the balloon. Before this altitude of vertical equilibrium is attained, and before the envelope is fully distended, a slight change of mass may cause a great change of level, because the altering volume of the globe nearly compensates the alteration of atmospheric density. Especially is this true if the framing and cargo have relatively slight bulk, as in a sounding balloon. But it is not well to assume, as some writers do, that the strength of the envelope will prevent the gas expanding, and thereby bring about static equilibrium; for the gas so confined may easily burst the balloon. For this reason, the neck of the envelope below is usually left open, or

[2] Centroid means centre of mass, which is commonly taken as the centre of gravity.

feebly closed, in order to relieve undue pressure when the bag is distended.

Simple applications of the foregoing principles are sometimes very useful in designing or understanding aircraft. In illustration we may take a few examples of balloon construction. But first let it be required to find the resultant pressure at the top of a vertical tube full of light gas, if the tube be open below and closed above.

At the open bottom of the supposed tube the pressures of air and gas are equal. At the top the air pressure is less than at the bottom by the weight of a unit square column of air having the length of the tube, while the gas pressure there is less by the weight of a gas column of the length of the tube. Hence at top the gas pressure exceeds the air pressure by the difference in weight of the columns of gas and air. Thus occurs a resultant outward pressure of the gas, which increases from nothing at the bottom to a maximum at the top of the tube, and at any other point is directly proportional to the distance from the bottom of the tube. This increase of outward pressure is, for hydrogen (roughly), 0.08 of a pound per square foot for each foot above the bottom of the gaseous column, near sea level.

From this simple example it follows that the resultant internal pressure in a hydrogen balloon increases one pound per square foot for each twelve feet above any fixed point in the envelope, the pressure at any given level being everywhere the same. It thus appears that if the envelope be very high, or have a long, vertical neck filled with gas, or if a long, unicellular dirigible rears up, the top pressure may become dangerously great. Ignorance or neglect of this consideration occasionally leads to monstrous and impracticable designs, and sometimes to disaster. Thus a balloon with a long neck has been known to burst at the top, as a cask is burst by pouring in water through a tall, narrow tube. A long dirigible has come to grief by rearing in flight so that the internal pressure caused the prow to explode. Designers of mammoth airships should, therefore, take precautions to ensure their colossal craft against splitting along the back or rearing and exploding at the prow.

From the foregoing principles, also, can be computed the bursting pressure of an envelope if the unit tensile strength of its fabric is known. If the envelope is spherical the entire

internal pressure on the area of the equatorial circle equals the whole tensile strength of the fabric around the circumference. In other words, to find the bursting pressure divide the entire circumferential strength by the equatorial area; or, more simply, divide the strength of one foot of the fabric by the radius of the sphere in feet. By similar reasoning it can be shown that the bursting strength of a cylinder is half that of a sphere of the same diameter, and that its resistance to splitting is half its resistance to tearing across. Of course, the top pressure in a well-designed balloon can never be allowed to approach the bursting pressure so computed, but a large factor of safety must be allowed.

In addition to the foregoing it may be sometimes desirable to know the strength of a long gas bag regarded as a beam, and subject to forces which tend to double it, as in Santos-Dumont's dirigible No. 2. The strength in such case can easily be computed in terms of the cross-section and internal pressure. Without giving the detailed proof, the following theorem may be stated: the breaking moment at any section of a round, inflated beam equals the whole internal pressure on the section multiplied by half the radius.[3]

The unit tensile strength of the fabric may be found by direct breakage in a testing machine, or by bursting spheres or cylinders of it by compressed air, due care being taken to measure the internal pressure and diameter at the instant of rupture. But the practice of novices, in which discs of the fabric stretched over the mouth of a tube are ruptured by fluid pressure, may lead to erroneous conclusions, unless the radius of curvature of the fabric at the instant of rupture be accurately determined, and the fabric itself be guarded from shearing, or cutting, at the clamp. If such measurements are correctly made, the tensile strength can be readily computed from the hydrostatic equations of the preceding paragraph.

The buoyancy of the gas in a balloon is the difference between its weight and that of the air it displaces. If it weighs half as much as air, its buoyancy is one-half the weight of said air; if it weigh one-fifteenth, its buoyancy is fourteen-fifteenths;

[3] A proof of this theorem is given in the present writer's paper, "Some Theorems in the Mechanics of High-Speed Balloons," presented to the International Aëronautic Congress, in 1900.

if it weighed nothing, its buoyancy would be fifteen-fifteenths, which is an increase of one-fifteenth over that of pure hydrogen. Thus it appears that in point of buoyancy an infinitely light gas balloon or a vacuum balloon would have no very great advantage, at least for ordinary use.[4] For sounding balloons and racers a lighter gas might be desirable if it could be retained.

The height to which a given balloon may rise may be found by dividing the total weight by the total volume of the distended balloon and its load, to obtain the density of the air at the level of balanced flotation, then reading in a table the altitude corresponding to that density. In formulating this rule it is, of course, assumed that no considerable weight of gas escapes during the ascent to the level of equilibrium; for every wise aëronaut leaves enough slackness in his envelope during inflation to take up the expansion of the gas during the ascent. The proper volume of gas to start with at the lower level must equal the volume at the upper level multiplied by the ratio of the atmospheric densities at the upper and lower levels, assuming that the gas possesses at those levels the temperature of the environing air, which it may do at night or when shaded by a dark cloud.

If the temperature of the gas be assumed equal to that of the environing air, or as might occur in a high-speed metal balloon of good thermal conductivity, it can be shown that the resultant internal pressure, or "net pressure," remains unaltered, however the temperature and barometric pressure of the atmosphere may vary. As this theorem is of some interest in the science of dirigibles, the following simple demonstration of it may be presented as first given by the writer in the paper above cited:

In the first place, if the atmospheric pressure alone alters, while the other elements remain constant, no change occurs in the net pressure. For the density of the air, and hence the buoyancy of the vessel, changes directly as the barometric pressure; and the vessel will rise or fall to a level where the density of the air is equal to what it was at the first position of equilibrium. But if the density at the new position equals that at the old, so also must the atmospheric pressure, since the other elements have not changed. Hence the net pressure is unaltered, which proves the theorem.

[4] For a mathematical proof of the impossibility of floating a vacuum balloon see the writer's popular treatise, *Aerial Navigation*.

Again, if the atmospheric and gas temperatures alter equally, while the other elements remain constant, no change occurs in the net pressure. For the density of the air varies inversely as the temperature; and the vessel will move to a level where the density is the same as at the first position of equilibrium. But if the density at the new position equals that at the old, the proportionate increment of air pressure must be directly as the increment of temperature, and therefore equal to the increment of gas pressure. Hence the net pressure remains unaltered, which proves the theorem.

Combining the two theorems just established, we obtain the more general one, *viz.*: if the gas temperature of a vertically free balloon keeps pace with the air temperature, no change of net pressure occurs for any thermometric or barometric changes in the atmosphere.

Furthermore, it may be affirmed that if the vessel's bulk varies, while its mass remains constant, practically no variation of net pressure ensues from the bulk change itself. For the pressure increments of the gas and air equal each other, since when the bulk enlarges or contracts the vessel moves to a rarer or denser atmosphere, while the gas pressure changes proportionately, thus leaving the net pressure practically unchanged.

Again, if air is pumped into or out of the balloon, practically no change of net pressure occurs if the balloon is free to alter its pressure accordingly, and if the temperatures of the gas and surrounding air remain equal. For changing the weight of air in the hull causes a corresponding change of atmospheric level, and with it a change of external pressure equalling the change of internal pressure. Practically this means that by pumping air into a balloon or its balloonet the vessel can be brought down from any elevation without altering the net pressure. This and the preceding theorem are rigorously proved in the paper previously cited.

The four theorems just proved assert that, in a high-speed metal balloon, practically no change of net pressure can occur from any change of density or temperature of the air, from any enlargement or contraction of hull, or from the alteration of weight caused by pumping air into or out of the hull, providing the vessel is free to float to its level of equilibrium.

Cerium Tin Alloys. R. VOGEL. (*Zeits. Anorg. Chem.*, lxxii, 319.)—The cerium tin alloys were investigated by the method of thermal analysis, combined with microscopic examination, and the equilibrium diagram of the system is given. The metals are miscible in all proportions in the molten state, and form the compounds Ce_2Sn, Ce_2Sn_3, and $CeSn_2$, which are highly exothermic and melt at 1400°C., 1165°C., and 1135°C. respectively. These alloys are attacked by water, with the evolution of gas, and those containing up to 50 per cent. of tin are rapidly oxidized on exposure to air; when they contain less than 80 per cent. of tin they are pyrophoric, and emit sparks when scratched. The maximum pyrophoric effect is observed with the alloy containing 30 per cent. of tin, which corresponds to the compound Ce_2Sn; and this also exhibits the maximum hardness. The cerium-lead alloys bear a general resemblance to these cerium-tin alloys.

Metallic Strontium. ANON. (*Eng.*, xcii, 2381, 242.)—Metallic strontium can be obtained by fusing pure strontium chloride in a hemispherical iron cathode vessel. This allows a low anode current density and avoids overheating. After applying a current of 125 ampères and 40 volts for seven hours, 76 grammes of metal can be removed in small lumps up to 3 grammes in weight. The metal is removed from the mixture by crushing on an iron plate and sifting away the chloride. It contains about 98 per cent. metallic strontium, which is a light metal with a silvery lustre when cut, gradually becoming yellow, and finally white and non-lustrous. It is softer than calcium and can be cut with a knife. It alloys with iron. Hydrogen and nitrogen combine with the hot metal. Its specific gravity is 2.55 and specific heat 0.0742, which corresponds to atomic heat 6.5. The iron alloy is rather hard and decomposes water; this alloy contains 23 per cent. of strontium.

Sulphalium—a New Alloy. ANON. (*Eng.*, xcii. 2378, 150.)—Valuable qualities are claimed for this alloy. It can be machined and cut with facility, as there is no dragging of the material nor clogging of files, as occurs with pure aluminum. Its melting point is about 1200°F., slightly higher than that of aluminum. It is about 3 per cent. denser than pure aluminum. Castings direct from the mould had a tensile strength of from 17,500 pounds to 21,700 pounds per square inch, and an elongation of 0.4 to 1.2 per cent. in a length of 4 inches. The elastic limit under compression in specimens 2 inches long and 1 inch in diameter is about 12,700 pounds per square inch. The fracture is granular and sound. Sulphalium is not affected by sea-water, and is used in large quantities for admiralty work. It is well suited for those parts of mathematical instruments which require stiffness and lightness.

THE PRACTICAL APPLICATION OF SCIENTIFIC MANAGEMENT TO RAILWAY OPERATION.

BY

WILSON E. SYMONS,

Chicago, Ill.

(Discussion continued.)

MR. W. V. TURNER, Chief Engineer, Westinghouse Air Brake Company: *Mr. President and Gentlemen:* I have read over rather carefully the paper written, or read, by Mr. Symons, and I am glad to say that I am heartily in accord with the sense of the paper as I understand it. I believe that the general intention of the paper is not against economic management; that any method, call it scientific management or anything else you please, is not discredited by Mr. Symons, but issue is taken upon the saving of one million dollars a day, the inference being that the railroads of this country are so mismanaged that one million dollars a day is being thrown away, or failing to be realized, because the gentlemen in charge do not practise scientific management, and that until these scientific management gentlemen came along, thirteen or fourteen years ago, everything was being run back-end foremost or without any regard to economy.

Mr. Symons, I think, has illustrated the point that if one million dollars a day would be *saved by scientific management of the mechanical department of our railroads,* it would be necessary to save one of every three dollars earned per man, and, according to Mr. Vauclain's figures, I think his men only earn two dollars per day; therefore, they would have to shell out a dollar a day to the railroads to help foot the bill. That would be rather a difficult proposition, and would not only be getting something for nothing, but, on the part of the men, a case of giving something for nothing, which would reduce the pay to about the same terms as those proposed by the scientific gentlemen, who have a lot of theories which, so far as my experience goes, have cost about a dollar and a half to work out for every dollar saved; this, however, is no argument against scientific management and applies only to this particular manifestation, or application of it.

I am not actively engaged in shop management at the present time, but I am connected with a firm that has been in existence now for forty-three years and under the jurisdiction of one

of the greatest men of this country. Its men are working under an economic system and are allowed to earn what they can, and there has been no strike nor symptoms of a strike in the forty-three years that the company has been in existence, and I do not think there is a stop watch in use. The men put forth their best efforts, and the result is that we have one of the best managed shops in this country, and there is no scientific management about it of the kind referred to in the paper.

To secure such efficiency in the Westinghouse Company organization involved the expenditure of large sums of money, and it was all spent to produce the articles manufactured by our company as cheaply and efficiently as possible. The railroads have been gradually improving their facilities and educating their men, and the school systems prove this by their results; but if they were to put in such a system as is proposed by this scientific management it would be necessary to spend many more millions of dollars before the new men and methods got a start; but when the railroads are selling transportation as cheap to-day as they were twenty years ago they must obtain money in some way. When, however, they ask permission to increase rates for the purpose of getting the money essential to the development of scientific management, they are told that this money, and more, is available if they would only save it. As well explain to the newsboy whose pockets are empty that there is money to be made selling newspapers. A rancher out West being without ready money to scientifically develop his property, but having a timber tract, thought to raise the necessary preliminary to this scientific management by disposing of his timber. To this end, it was necessary to purchase a sawmill, and he therefore wrote to a manufacturing concern for prices, etc. They obtained information as to location, and quantity, character, etc., of the timber, and quoted him a price of $10,000. This surprised Mr. Ranchman considerably, as he did not expect that scientific management would require any such initial outlay as this, and he answered the quotation by a hot wire as follows: "If I had $10,000, what in Hades do you suppose I would want with a sawmill!" If the railroads have money enough to inaugurate scientific management, a raise of rates would not be necessary, as we are told that they would be able to add a million dollars a day to their treasury without it. In fact, Mr. Emerson has now raised this estimate to five million dollars a day.

Gentlemen, the worst feature about the whole proposition, as it appears to me, is the desire to get something for nothing; to inaugurate a revolution without cost; to do it by means of stop watches and bonuses (another name for premiums on bad work and concealed defects), and by the pitting of one man against another to the exhaustion of all physical and mental energies, making life a mere drudgery, with neither time nor disposition to find out that it is good to be alive.

No one believes more in getting the *best* efforts out of a man than I do, but it can be done by encouraging him and giving him more enthusiasm, and should not be done by spying upon him or giving him less care or thought than the machine he is working upon. I was on the Santa Fe when this system was inaugurated, and, undoubtedly, there was room for considerable improvement, but I must confess that I am not prepared to unqualifiedly indorse the means employed to effect it or the quality of work resulting. However, we are told that these methods will in some way produce the money with which to buy more machines, more locomotives, and more cars, and I suppose we ought to be satisfied. It reminds me of a story told on J. J. Hill. Shippers were kicking because they were not supplied with either enough cars or as promptly as they desired, and he advised them that he would furnish cars and made preparations to issue bonds to buy cars, at which they got out an injunction to restrain him. He turned to them and said, "Gentlemen, if you will furnish the cars, I will haul them for you," and this illustrates pretty well about how the matter stands. No doubt, Mr. Clarke and Mr. Hill and other gentlemen connected with our railroads would be only too glad to get out of it all that there is in it, and the fact that they desire to obtain money with which to inaugurate scientific management shows that they desire to profit from the advice and by the assistance of the efficiency engineers, but to realize it in perhaps a little different way; that is, supply the man with tools and all other things necessary to do his work, but at the same time allowing him to remain under the impression that he is still a man.

A. L. CONRAD, Assistant General Auditor, The Atchison, Topeka and Santa Fe Railway Company: *Mr. President and Gentlemen*: I have been very much interested in listening to this discussion, but did not come prepared to take any active part

therein; therefore must beg to be excused. However, in view of the direction taken by this discussion, dealing largely with results obtained under the so-called scientific management plan on the railway with which I am connected, I will say that there are many elements entering into the equipment repair performance reflected in the Atchison repair accounts, such as contributions of new engines, changes in weight, tractive power, and type of engines, etc., each of which has had considerable influence on the unit costs of repairs during the period covered by Mr. Emerson's administration and since that time, and when these elements are fully analyzed and each given its due weight and importance it is believed that there will be found no substantial reduction in repair costs during the Emerson period; neither will it be found that there has been any diminution of efficiency or practical application of scientific management in the subsequent period in which our mile-run unit costs are shown to be considerably higher.

I will add that from my personal observation and study of this subject I believe there is much to be gained from a scientific study of the conditions surrounding the performance of all mechanical operations and theorizing thereon, as both lead to the elimination of much wasted energy; but, like everything else, this application of science and theory has its limitations and must be coupled with practicability and consideration of the human equation, as it requires a harmonious combination of all of these factors to secure profitable results. The so-called scientific management, including the profit-sharing or premium-paying plan, that has been so widely advocated and which is the subject under discussion, is, in my opinion, much less adaptable to railway repair shops and operations performed therein than to large machine shops and manufacturing plants where the output can be accurately and inexpensively measured as to quantity and quality.

MR. EMERSON: It is unkind to criticise Mr. Wilson E. Symons's address, "The Practical Application of Scientific Management to Railway Operation." Mr. Symons quotes the Bible. He will remember the story of Balaam, who, being employed by Balak to curse Israel, blessed instead, and when Mr. Symons blesses we heartily agree. Mr. Symons shows at length that in

the matter of lubrication railroads were formerly very wasteful, but that this small item of expense has been decreased 233 per cent.; that "the total saving since 1890 is not less than $100,000,000; the annual saving to the railroads may be estimated at about $10,000,000 a year, which justifies classing Gen. Charles Miller as a leading efficiency engineer."

Some of my friends and clients were interested in the Galena Oil Company for many years. For three years I carefully studied its plans and operations. I have been consulted by its officials. I have expressed to General Miller my great obligation to his teachings, and I agree with Mr. Symons—

Firstly, that General Miller is an eminent efficiency engineer;

Secondly, that his technical methods are those of efficiency engineering;

Thirdly, that his methods have probably saved the railroads $100,000,000 in twenty years and are saving the railroads $10,000,000 on the single item of lubrication.

What were the efficiency methods put into effect by General Miller?

Formerly lubricating oil was purchased and used without investigation of quality or special properties.

General Miller established laboratories, employed experts, tested oil from raw product to finished application. He and his experts knew more about oil than all the railroad employees in the United States. He entered into contracts with the railroads on a mileage basis. His contention was that it was not price per gallon but quantity used per mile that counted; that in the equation Q P the railroads could obtain a minimum, not as they were doing, by reducing Price and increasing Quantity, but by increasing Price and reducing Quantity. The railroads were at first staggered at the proposition to pay $0.36 a gallon for oil when they had formerly paid only $0.18, but as better results were guaranteed by the Galena Oil Company than they could obtain themselves, they acquiesced, and it is said 98 per cent. of the railroads of the United States have mileage lubrication contracts with General Miller's company.

I was not in the slightest interested in the price obtained for oil by the Galena Oil Company, but it is an efficiency principle that better quality at a higher price is economical, and this principle applies to materials, to supplies, to labor, and to equipment.

Whether the railroads could or could not have made a better bargain with the Galena Oil Company as to price is a different question from that of economies in use. Personally I am always willing to pay more for materials, for labor, for equipment, if increased price results in less quantity.

The Galena Oil Company having secured a contract, the easy part of its work, took up with equal intelligence the use of the oil it had sold.

Engineers, car oilers, and others, who had been accustomed to "Gospel measure," "full and running over," were not easily converted to the use of one-third, or even one-sixth as much oil.

Mr. Symons states: "As a result of the oil contracts, the oil company furnished experts free of charge to supervise the economical use of the oils, and in the co-operation of these experts with mechanical and operating officers many improvements in the design and repairs of motive power, handling of equipment, stores, and supplies have been accomplished."

It was these methods, these experts, I most carefully studied and watched. The oil company with a contract on a big road was willing to pay more for experts, for organization to look after oiling alone than the railroad was willing to pay a superintendent of motive power and his direct staff for looking after all motive-power conditions. The experts of the oil company boarded locomotives, cultivated the friendship, stimulated the interest of engineers, took up their difficulties, co-operated with them, persuaded them not to use $0.36-per-gallon oil to light the fires, perhaps even discovered that all elevators and mills along the line of the railroad were using railroad oil and other supplies, and this practice they stopped. By constant, unremittent personal attention to men and conditions, supplemented by the quality of oil used, the Galena Oil Company made good. Its methods were those of Scientific Management:

(1) As complete knowledge of the subject as the state of the art permitted;
(2) An organization to realize ideals;
(3) Equipment to supplement the organization;
(4) A strong executive who understood, who directed and who through organization and equipment accomplished.

If $10,000,000 a year is being saved on oil, the total lubrica-

tion bill for all railroads now being about $21,000,000, what could not be saved on a $525,000,000 material bill, on a $1,019,000,000 labor bill, on a $1,210,000,000 equipment charge, if the methods of Gen. Charles Miller—investigation by experts—application by experts—were applied?

With the example of Gen. Charles Miller's work before me, with thirty years of railroad experience covering all departments, with fifteen years' experience as investigator, manager, and efficiency counsellor to various industrial and transportation enterprises, I know that the expenses of operating and maintaining the railroads of the United States could be reduced several hundred million dollars a year.

This reduction could not be effected without the earnest, patient, wise, and just co-operation

Of railroad owners;
Of railroad employees;
Of the public, both individually, corporately and represented by its State and National Government;
Of a great body of competent efficiency counsellors and scientific managers.

This reduction in expense can be brought about with great gain to each of the four classes, not at the expense of any class for the profit of any other class.

Railroad owners, until they had been paid off in full, would hold securities of more stable and greater market value than those they now hold. It is not necessary to confiscate one dollar of present market value of railroad securities. Individual railroad employees, from presidents down, should receive increasing compensation for less toil, strain, anxiety, and effort, and it would not be necessary or be any part of the plan to discharge or lay off or throw out of work a single employee on account of the application of efficiency principles.

The public would ultimately benefit from the very great reductions in current expenses. This benefit might take in part the form of better service—elevated tracks through cities, electrification, steel cars, faster trains, more trains, palatial and commodious stations—it might take in part the form of reduced rates for both passenger and freight service.

Reforms of this magnitude cannot be put through without utilizing the highest experience available.

This highest experience cannot be obtained solely from the ranks of railroad owners, nor solely from the ranks of railroad employees, nor solely from the representatives of the public, nor solely from the great body of scientists and specialists who have given their lives to acquiring knowledge and skill in various directions.

The highest experience must be collated and applied by the co-operation of all those who know.

An example of supplementing knowledge occurred on the Rock Island. The water chemist, analyzing all the tank waters, reported one as particularly bad, and advocated the erection of a purifying plant. Mr. Mudge, vice-president, knew that more serious trouble occurred elsewhere than at this particular tank. He checked up the quantity of water used at each tank and showed that a water with only one-quarter as many grains of incrusting solids per gallon, but used for twenty times as many locomotives, was causing five times as much trouble. A purifying tank was approved for the pure water. This illustrates the difference between System and Efficiency, also illustrates the advantage of combining the knowledge of the man who can analyze water with the knowledge of the man who knows railroading in its length, its breadth and its depth.

Demagogues as well as many well-meaning deeply-interested but ill-informed have preached to labor that savings can only be effected by adding to the burden or lessening the compensation of labor.

The public is for the moment satisfied that rate increases have not been granted. The public like the workers has listened to demagogical assertions, and vaguely thinks that rates might be lowered to the extent of a million dollars a day, when in fact railroad owners and managers, as well as the governments representing the public, have many serious problems to solve before any reductions are in order; and if enormous terminals and expensive way stations are to be built, if tracks are to be elevated, if smoke nuisances are to be abated, if wood in equipment is to be replaced by steel, if wages are to be raised and hours shortened, the public will have to face higher rates, and higher rates will serve it right.

At present there is not the co-operation between the four classes interested that there ought to be.

Efficiency experts have asserted

(1) That stupendous wastes exist in railroad operation;
(2) That the application of efficiency principles would eliminate these wastes.

The railroads have countered with a general denial that any such wastes exist, or that they could be eliminated even if they did exist.

Why not test the matter out?

Mr. Brandeis, an eminently successful practical efficiency expert, has offered to place knowledge and expert skill at the disposal of the railroads without charge. Not one has accepted his offer.

Other efficiency engineers are willing to undertake the reduction of unit costs on the same basis as Gen. Charles Miller uses, namely, for a contingent fee. The offers are spurned. They are willing to carry out test analyses free of charge. They are scoffed at.

We told one eminent railroad manager that the wastes on his road amounted to $2,700,000 a year. This was in 1907. He was very indignant, told me that he knew it as well as I did, and that he proposed to eliminate them without the help of Scientific Experts as to inefficiency. The next year, 1907–8, his expenses went up $2,300,000, or $5,000,000 above what they ought to have been.

We were invited to check up another trunk line. My associates discovered wastes of over $2,000,000. The same railroad was checked up by a very eminent and successful railroad executive. Pursuing wholly different methods, he also estimated annual preventable losses at $2,000,000. Ten weeks after we had presented our report I was told that it would be unfair to the road and to its officials to allow any outsider to offer advice or suggest remedies. He had never paid for the information given. This was according to the principles of strenuousness, but not according to efficiency principles.

I recall with pleasure an experience of twenty years ago. I was engaged by the Burlington to look after its tax matters.

For a fee of $1,000 I offered to do the same thing for another great line, the Union Pacific. My offer was refused because the officials could not see what excuse they would have to pay me $1,000 to attend to their business. Inside of a month I bought in their delinquent taxes in my home county and scooped $3,000 in penalties without investing a dollar. It was the sweetest money I ever earned.

I have read with great care Mr. Symons's brief against the use of Scientific Management in railroad direction, maintenance, and operation. My own theory is that the railroads, to a higher degree than industrial plants, apply Scientific Management, and it is due to this higher degree of application that in so many respects railroad operation is so excellent.

The predetermined precision with which very fast trains run in all weathers over long distances is one of the best examples the world has ever seen of the accurate and perfect results resulting from Scientific Management. Railroads were originally organized to transport passengers, and in this they have attained a high degree of excellence as to speed, safety, and comfort.

Mr. Symons's argument against applying available knowledge and skill to the details of railroad operation, except as to lubrication and air-brakes, can be reduced in substance to a few definite propositions:

(1) That the man who said the preventable wastes of railroads amount to $1,000,000 a day is an academic theorist or student without practical knowledge of transportation problems or of the applications of Scientific Management of these problems.
(2) That practical railroad men know their own business and need no advice from theorists as to how to run it.
(3) That the practical application of Scientific Management to the Santa Fe was a failure.
(4) That as a practical railroad man he sees possibilities of savings of $78,000 a day, which is much less than $1,000,000 a day.

It does not seem to me that Mr. Symons knows either the aims, methods, or results of efficiency principles applied to railroad operations, for if he knew, he would not endorse the in-

vestigations and methods of the Galena Oil Company, claiming for them an annual saving of $10,000,000, yet object to expert investigation and co-operative methods as to all other items of railroad expense.

What is Scientific Management?

It is the common-sense and economical application of all available knowledge and skill to every part of operation, however great—$1,000,000,000 of wages, for instance; however minute—lubrication, for instance.

The aims of Scientific Management applied to railroads are:

(1) Not to ask for the discharge of a single man on account of the introduction of efficiency methods.
(2) To lessen the toil, hardship, danger and friction, fluctuation in employment that at present in greater or less degree affect every railroad employee, from president down.
(3) To increase the pay of those who are carrying on railroad work.
(4) To increase the security and value of railroad investments.
(5) Ultimately to lessen the costs of service to the public.

In 1908, in a contributed article written at the request of *The Railroad Gazette*, I ventured the opinion that small inefficiencies following one another in dependent sequence resulted in terrific end inefficiencies, and that owing to the great number of dependent sequences in railroad work the losses aggregated $300,000,000 a year. This essay was favorably commented on by railroad publications, and I did not hear a single adverse comment.

In February, 1910, nearly two years later, I repeated the statement before the Railway Club of Pittsburgh, at which time there was violent dissent by railroad men.

In November, 1910, Mr. Brandeis startled the country by his dramatic presentation of the argument against rate increases before the Interstate Commerce Commission, and he put me on the stand to state how I had arrived at this estimate of $300,000,000.

In preparation for that hearing and during the past year I

have been obliged to study and analyze more carefully than before the different items of railroad expense, and these studies and analyses, in which I have been assisted by very able men of lifelong railroad experience, have caused me to revise my estimate of one million dollars a day, and with due and deliberate consideration I now place the ultimately preventable wastes at two million dollars a day—losses to be eliminated by increasing, not decreasing, the efficiency of the roads both as carriers, earners, and employers.

Mr. Symons puts the words "efficiency engineer" in quotation marks, and under the heading "Efficiency Engineers—Who Are They?" he quotes from an article in *Hampton's Magazine*, written by a man of no technical or engineering training, absolutely without efficiency reputation or efficiency experience of any kind, an article against whose sensationalism I protested to the editors of the magazine, a magazine recently in difficulties of another kind with the United States authorities.

The implication by Mr. Symons that efficiency engineers and Scientific Management experts belong in the same class with irresponsible sensation mongers and muckrakers is not in accordance with the efficiency principle of "The Fair Deal" or the efficiency principle of "Common Sense." Personally I cannot allow that Mr. Symons's railroad experience has been either longer, broader, or more varied than my own. As I have assumed to speak of railroad conditions and problems, it is but just to our audience to let it know that it is not listening to an irresponsible theorist without practical experience.

I was on the far frontier in railroad work thirty-five years ago. For thirty-five years, including the present year, I have travelled on railroad passes because engaged in railroad service. I have been employed by six trunk lines—three western and three eastern—I have been directly on the staff of two railroad presidents, of several vice-presidents, and of general managers. I was for a year on the staff of one of the greatest superintendents of motive power America has produced: a man also eminent as a scientific railroad manager. My assistants have come from a dozen trunk lines.

I have sat in business specials from the shores of the Atlantic to those of the Pacific, but I have also slept in box cars with the laborers on grade. On frontier surveys I have gathered pebbles

to soften the hardness of my bed on the bare ground. I do not pose as an operating railroad expert or as an expert in any branch of railroading. As to all facts and theories I have always taken counsel of those more experienced than myself; nevertheless, few men of my age have a larger or more varied general acquaintance with railroad operations. So much for the parlor theorist.

This knowledge is, however, not necessary. I was an efficiency engineer before I touched railroading. I have been in efficiency practice since I stopped railroading. My associates have gone into plants which had no connection with railroading and achieved results, because Scientific Management rightly applied always achieves results. Science is not a method, a device, a system; it is a truth based on an understanding of the laws of the universe.

I deny, therefore, absolutely that a man who has thoroughly grasped the fundamental principles of organization could not apply them to insects, to birds, to the animals in a menagerie, to packs of hounds, to savages, to railroad lubrication, and to civilized men. I deny absolutely that I would have to be a Chinaman to apply efficiency principles to a Chinese railroad or to a Chinese caravan.

As to the second contention, namely, that railroad men can manage their own business without asking counsel, railroad men know better. As to legal matters, they consult lawyers. As to railroad accounting, they have been guided by chartered accountants, who applied to railroads the fundamental principles of all accounting and who displaced the earlier, primitive, inadequate, and faulty bookkeeping methods. As to lubrication, certainly a practical detail of railroad operation, 98 per cent. of them have sought the advice and assistance of the Galena Oil Company.

Recently Congressman Redfield, of Brooklyn, in a humorous talk at Dartmouth College, told the manufacturers of New England that the great trouble with them was that they knew their own business so well that nobody could teach them anything. His sarcasm was applauded by the men he was addressing. A great labor strike is now in progress on the Harriman lines. The railroad employees know their own business so well that they can't take advice, and the railroad officials know their business so well that they also feel quite competent to manage

their own end of it, and in the meantime violence and outrages that would be disgraceful in the Congo Free State are of daily occurrence. The shopmen don't think the managers know how to solve railroad labor problems justly, and the managers do not think the shopmen have any conception of the magnitude of the problems.

It is said that a few years ago the Big Four lost $623,000 by defalcation; more recently, on the Illinois Central, car repair frauds ran into millions—both these frauds an absolute impossibility under the charts and standards of Scientific Management, since any deviation from standard would at once have been investigated. When any body of men assume to know it all, to be above all advice and advance, they have become Bourbons, who can neither forget nor learn. Knowing a great number of progressive railroad men, having all my life been associated with progressive railroad men, I would be sorry to accept Mr. Symons as speaking for them.

Mr. Symons states that Scientific Management has been a failure on the Santa Fe.

He seems to mean by failure that expenses as to some items are not as low as on some other roads. Is the feature of economy all he considers in Scientific Management?

Even as to economy we shall answer him, but there are more important matters than the dollar.

On the Harriman lines, namely, the Union Pacific, the Southern Pacific, and the Illinois Central, at the present time an acrimonious and bitter strike of the shopmen, freight handlers, and others is in progress.

The Santa Fe lies in the triangle formed by these three roads. There has been no strike of the shopmen on the Santa Fe for seven years and there is none now. Strikes were a continuous performance before 1905. During the whole of the last seven years there have been strikes on other roads—the Erie strike that lasted several years, the strike that sent the Chicago and Great Western into the hands of a receiver, the recent Pennsylvania strike, and many others.

The shopmen on the Santa Fe have not found it necessary to strike, because under more favorable work conditions they received more per hour than other Western railroad workers, and the railroad company had no complaint, because the more the

shop men earned, the lower the unit costs. I quote from different reports of Mr. J. W. Kendrick, at the time of the statements, vice-president in charge of operation:

"Our rates, including bonus, are considerably higher than those of other roads in the same territory. This is what was intended in the first place."

"We have between twenty-five thousand and thirty-five thousand schedules in force, and since 1905 the average efficiency of workmen employed on bonus has increased from about 60 per cent. to 93 per cent."

"The total expenditure on account of bonus payments and bonus supervision, etc., in 1910 was at the rate of $1,283,000 a year."

"As the efficiency of our shops increases, it follows that the premium payments must also increase. The company has looked on this growth of premium payments with a great deal of satisfaction."

In 1903 I was recommended to Mr. Kendrick, the new vice-president of the Santa Fe Railway, by the second vice-president, Mr. Paul Morton, whom I had known for many years.

The problems demanding solution on the Santa Fe in May, 1904, were four, and I name them in the order of their importance:

(1) To maintain equipment with nearly all the mechanical employees on strike and violently and destructively hostile.

(2) To take care of a rapidly-increasing business without time to increase shop facilities and equipment. The freight business increased 40 per cent. in three years, the passenger business 30 per cent., with almost no new equipment added.

(3) To restore harmonious relations between employer and employee—relations that had been strained and embittered for many years.

(4) To reduce unit costs which had been steadily rising for a series of years. This was never an aim. It was believed that unit cost reduction would necessarily follow increased efficiency.

Each of these problems was put in the way of successful solution owing to the untiring and intelligent support given by Mr. Kendrick, vice-president.

I believe I am the only professional efficiency engineer ever employed by the Santa Fe. Between January, 1904, and September, 1907, I advised Mr. Kendrick as to certain small problems affecting only one or two departments; also, between April, 1904, and March, 1907, I collated, put in shape and superintended the introduction of certain efficiency principles as to mechanical operation, especially the practical principles of records, reliable, immediate and adequate; planning, despatching, schedules and standards.

In March, 1907, I moved from Topeka to New York, taking up, to me, more important but less interesting work. The general work of "betterment," as we called it on the Santa Fe, was transferred to railroad men of very great ability and experience. Mr. Kendrick continued to take great interest in the work, showing an unusual courage, ability, and energy in prosecuting it.

Mr. Buck, who was appointed superintendent of motive power, was an able railroad man of long and successful mechanical experience.

Mr. H. W. Jacobs, a young man of great energy, who had had railroad experience on the Burlington, on the Missouri Pacific, on the Union Pacific, and on the Santa Fe, was appointed assistant superintendent of motive power. Whatever success or failure attended their efforts on the Santa Fe after June, 1907, is due to railroad men and railroad methods, not to efficiency engineers or to a strict or even general application of the principles of Scientific Management.

The efficiency organization, small and inadequate, which was built up on the road between 1904 and 1907 was disbanded. Some of my assistants were retained, others followed me to New York. A very much larger but distinctly systematizing railroad organization was created, taking the place of the small organization of expert efficiency advisers. Before Mr. Buck was appointed, mechanical expenses began to increase.

The increase was, in my opinion, not due to personality, because all the men mentioned were exceedingly able, but it was due to inability on their part to dislodge from their minds the old

railroad conceptions of management and control and substitute for them the principles of Scientific Management. Methods were extended, but principles were lost sight of.

In modern organization it is the function of staff experts, however employed, to evolve standards and experimentally show that they can be attained; it is the function of line officials practically to realize and maintain the standards demonstrated by the staff. This distinction between staff and line was not maintained after June, 1907, on the Sante Fe; the peculiar and special duties of staff were largely added to those of line.

Even though in 1905–6 and 1906–7 the principles of Scientific Management were only partially applied on the Santa Fe, it is fair to hold them responsible for whatever changes for better or for worse occurred in these years as compared to the years immediately preceding, omitting the year of the mechanical employees' strike, 1904–5. It is not fair to cite the Santa Fe as an example of the results of Scientific Management in years subsequent to 1906–7, since the work was neither extended nor supervised by any efficiency engineer. There is a great difference between System and Scientific Management; there is even a greater difference between strenuousness and efficiency—strenuousness expecting greater results from more effort, efficiency expecting greater results from less effort. Betterment work on the Santa Fe has been systematized; there has been a strenuous but not always efficient endeavor to extend its scope. Those in charge of it, railroad men as is Mr. Symons, are abundantly able to defend it against his attacks. I do not know whether expenses per unit have increased or not. I no longer have the unit records. The road is using some locomotives twice as heavy as when I was with it. These are new types, necessarily costly in the experimental stages. The cost of repairs per mile or per locomotive is not to be applied comparatively to locomotives weighing respectively 66 tons and 425 tons, costing respectively $7,740 and $43,880. I confine myself to the period when the road as to its mechanical operations was counselled by an efficiency engineer, supplemented by an efficiency staff.

As to the maintenance of equipment with employees in strikes, I quote from the president's annual report, 1904–5, page 13:

"Equipment is in better condition than ever before, notwithstanding the adverse conditions of the past year (strike), and the road is now prepared to handle promptly and efficiently a large prospective business."

The equipment maintenance conditions were serious in May, 1904, on the A., T. & S. F. Ry.

(1) An enormous increase in business was beginning.

	Passenger miles in millions		Freight ton miles in millions		Number of locomotives	
1903	613		4,706			
1904	708		4,682		1433	
1905	744	increase 37 p. c.	4,730	increase 46 p. c.	1454	increase 25 p. c.
1906	865		5,841		1676	
1907	970		6,843		1791	

(2) Because the annual increase in business could not be foreseen, it was impossible to order new locomotives in time to take care of it. It was also impossible to build and equip new shops in time to take care of the increased deterioration of overloaded old equipment and added new equipment.

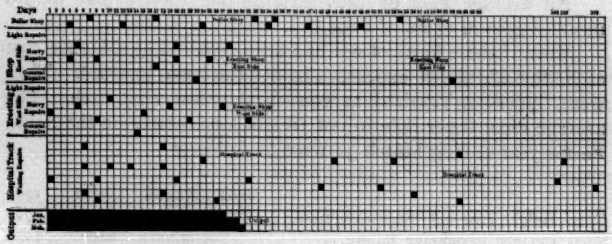
So great was the increase between 1904–5 and 1906–7 that President Ripley states, page 20, report 1906–7: "At times the increase in volume of traffic was so large that the company's equipment was overloaded. The necessity of moving traffic without regard to economy of operation caused a material increase in operating expenses."

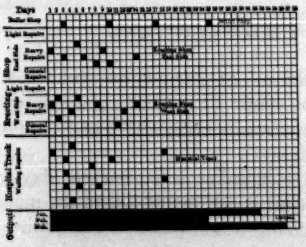
The International Association of Machinists, which in 1903 had won a successful strike on the Union Pacific, thought the time propitious to force concessions, and made proposals to the A., T. & S. F. Ry. President Ripley's words, Report 1904, page 19, are: "Certain unreasonable demands made by the International Association of Machinists having been declined, that organization declared a strike at all shops of the company, effective May 2, 1904, which order was quite generally obeyed on the western portion of the system, as well as by a large number of employees on the eastern divisions."

The shops, therefore, in May, 1904, found themselves quite generally without employees and with run-down and crippled equipment, the bad conditions being largely due to the hostility of several years' standing of the employees towards the employer, a hostility always conducive to neglect and worse.

Yet even under these difficult conditions, when expenses of track maintenance and of operation were rising, the expenses of maintaining equipment were falling.

The diagrams show the detention of locomotives in the Topeka shops at an interval of a year on the two dates, March 30, 1905, and March 30, 1906. Each black square represents a





locomotive, and the position from left to right shows the time of detention for repairs. The total number of locomotives discharged from shop was

	1905	1906
January	27	32
February	29	24
March	30	36
	86	92
Total days of detention:		
March 30	1,735	254
Gain in locomotive days		1,481

Each locomotive's service per day was estimated to be worth $35 to the company.

	1902-3	1903-4	1904-5	1905-6	1906-7
Gross earnings per day	$171,000	$187,000	$187,500	$214,000	$256,500
Divided by locomotives in service	131	130	130	131	143

An average gain of 1481 days at one shop in one month meant a gain in gross of $194,011.

Even if these locomotives had been repaired at a higher cost each, the additional expense would have been justified. They were, however, repaired at considerably less cost each. The average records per mile run of freight locomotives on the Santa Fe for year ending March 31 were as follows:

	1904	1905	1906	1907
Gross freight tons per locomotive mile....	686	685	725	765
Miles run per locomotive failure.....		3,100	4,900	4,250
Coal used per locomotive mile, pounds....			243	241
Repairs per locomotive mile, cents.....	11.34	12.56	9.63	9.40
Per cent. of locomotives in shops for repairs		20	19	19

As to restoration of harmonious relations, the absence of strikes among the Santa Fe mechanical employees, the occurrence of strikes on other roads everywhere and none on the Santa Fe, is the best testimony.

Why should men strike when current day rates are guaranteed, when overtime is eliminated, when the management does its part in standardizing conditions and facilitating standard operations, when the worker is paid an extra sum for the exercise of intelligent supervision, when he is freed from tyranny, when his gross earnings are increased on the average nearly 20 per cent., in some cases as much as 100 per cent., when his net earnings, that is, the margin between minimum living costs and gross income, have been increased several hundred per cent.?

The operation of the equipment, taking care of the increased business, harmonious relations, these were the main aims sought both by the vice-president, Mr. Kendrick, and by his efficiency staff. If cost reductions occurred they were a welcome by-product due to increased efficiency, but not to increased strenuousness.

The story of the attempt to apply the principles of Scientific Management to some departments of the Santa Fe has been told at length elsewhere, and those interested are referred to these sources of information.[1]

Nevertheless, even as to economic results I take up Mr. Symons's challenge.

Economies in railroad operation can be comparatively ascertained only when reliable units or standards are used.

Railroad units valuable for comparison are a subject of extreme technicality, almost out of place in a public discussion. Some of the difficulties will be indicated. How shall the performance of locomotives be compared? What unit shall be used?

Locomotives vary in weight from a few tons up to 400 tons.

The mileage in a year may run from nothing up to 70,000 miles.

The tonnage hauled may run from nothing up to 3000 tons.

On mountain divisions the cost of repairs per unit of work performed is 60 per cent. greater.

The efficiency of some shops where locomotives are repaired is 100 per cent., of other shops it is as low as 30 per cent.

What unit shall be used to compare locomotive repairs? The locomotives? The mileage? The tonnage? The division? The shop? Each is absolutely absurd unless all other conditions are similar. There is a further consideration. What is included in the costs to which any one of these units is applied? Shall it be the moneys actually expended in locomotive repair, or shall it include in varying degree such items as the purchase of new locomotives to replace old locomotives scrapped, the maintenance and renewals of shop machinery and tools, supervising expenses of all kinds, extraordinary expenses, or those for guards during a strike?

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[1] Betterment Work on the Santa Fe, 1906. (Reprint from *American Engineer and Railroad Journal.*)

Shop Betterment and the Industrial Effort Method, 1905.

Securing Efficiency in Railroad Work.

Story of an Attempt to Apply Scientific Management to Some Departments. Lecture delivered at Harvard University, November 16, 1910, before the rate hearing in Washington. (Reprinted by the Emerson Company, 30 Church Street, New York.)

Mr. Symons makes Santa Fe comparisons when the conditions vary as follows:

	1902-3 Tons	1903-4 Tons	1904-5 Tons	1906-7 Tons
Average weight of locomotives.....	68.76	74.91		81.74
Average weight on drivers.....	54.37	58.63		62.66
Average mileage		36,344	33,868	29,210
Average road units	43,422	47,251	47,855	64,629
Average tonnage hauled		686	740	775
Indirect expenses added to direct locomotive maintenance cost.....	15%	18%	18%	16%
Strike conditions	None.	2 mos.	12 mos.	Overcome

Even with these variations in the comparisons and with locomotive conditions most variable, I cannot find any comfort for Mr. Symons in his attack on Scientific Management.

If a locomotive made no mileage it would need no repairs, therefore cost of repairs per mile run is a better basis, although still very unsatisfactory, as one road might haul small tonnage and the other heavy tonnage.

COST PER LOCOMOTIVE.

	1902-3	1903-4	1904-5	1906-7
Santa Fe	$3,042	$3,772	$4,165	$3,033
Southern Pacific	3,288	3,588	3,473	3,444

AVERAGE WEIGHT IN TONS OF LOCOMOTIVES.

	1902-3	1903-4	1904-5	1906-7
Santa Fe	68.7	74.9	77.5	81.8
Southern Pacific	56.2	59.7	64.	67.2

COST OF REPAIRS PER TON OF LOCOMOTIVE WEIGHT.

	1902-3	1903-4	1904-5	1905-6
Santa Fe	$38.45	$50.35	$53.57	$37.08
Southern Pacific	58.35	60.12	54.35	49.82

MILEAGE PER LOCOMOTIVE.

	1902-3	1903-4	1905-6	1906-7
Santa Fe	30,506	36,344	33,868	29,210
Southern Pacific	38,154	34,741	30,940	33,976

COST PER LOCOMOTIVE MILE.

	1902–3	1903–4	1904–5	1905–6
Sante Fe	$0.0867	$0.1134	$0.1256	$0.094
Southern Pacific	0.0862	0.1033	0.1123	0.1048

We have a better unit than either locomotive or mile if we take weight or drivers multiplied by mileage and divide by 100,000,000.

COST PER ROAD UNIT.

	1902-3	1903-4	1904-5	1906-7
Santa Fe	$80.00	$96.63	$105.92	$72.60
Southern Pacific	93.98	101.71	109.27	89.55

These comparisons, lacking identity of units, are wholly unsatisfactory, since there are variations in mileage, in weight, in costs of labor and materials, in tonnage hauled, in climatic and in labor conditions.

It would be absurd to draw very close conclusions as to efficiency, but at least the last year, 1906–7, on the Santa Fe does not suffer in comparison either with the year 1902-3 nor with the parallel road, the Southern Pacific, in any year.

While these reductions were occurring in locomotive repair costs under partial application of efficiency principles, what was happening as to maintenance of way and structures per mile without Scientific Management?

1903–4	$1,121	1905–6	$1,479
1904–5	1,371	1906–7	1,648

Not knowing the units, not knowing what was being done, what great washouts had occurred, no unfavorable inference can be drawn. It is possible that the low cost of 1903–4 was relatively higher than the high cost of 1906–7.

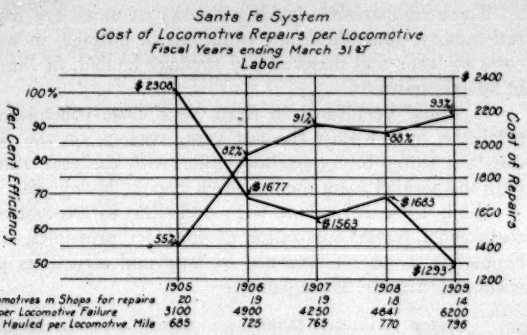
These comparisons, flattering though they are to Scientific Management, both as to the Santa Fe compared with itself in different years and the Santa Fe compared with the only other comparable road, the Southern Pacific,[2] they are nevertheless not the kind of comparisons Scientific Management would make except in the most popular manner and with apologies.

[2] Both running through the same states—California, Arizona, New Mexico, Texas—both having same mileage, same number of locomotives, both having oil burners, labor and physical conditions being similar for both.

They are not the kind of records called reliable, immediate, and adequate. Happily there are other corroborating records, although we cannot forbear introducing one other diagram, a railroad man's diagram, printed in one of the official reports of the Santa Fe.

This diagram does not extend further back than 1905.

The cost of the maintenance of shop machinery and tools on both the Santa Fe and on the Southern Pacific, both actual expenses and per unit, the unit selected being based on combined mileage and weight on drivers of all locomotives, make a better comparison.



Here is a distinct test, this department of the Santa Fe being pitted against its own past record, pitted against a predetermined cost allowance, pitted against the records of the corresponding department on the only comparative road. The Santa Fe started 7.4 per cent. behind, $10.31 as compared to $9.55 on the Southern Pacific. In the first year of the race the Santa Fe was struggling with strike conditions, the Southern Pacific was operating normally; in fact, in the month in which Scientific Management was first applied on the Sante Fe the preceding average yearly cost had risen to $11.10 per unit. The main and chief difference between the two departments was that on the Santa Fe the work was being advised and directed by efficiency counsel and staff experts, and on the Southern Pacific it was being directed in the usual way by railroad line officials unassisted by staff counsel.

MAINTENANCE SHOP MACHINERY AND TOOLS.

A., T. AND S. F. RY. (SANTA FE).

Year	Units	Expense	Unit Cost
1903–4	47.250	$487,171	$10.31
1904–5	47.854	486,620	10.16
1905–6	57.760	376,106	6.51
1906–7	64.628	315,844	4.89
SOUTHERN PACIFIC.			
1903–4	51.003	$487,150	$ 9.55
1904–5	52.037	567,161	10.90
1905–6	57.034	537,318	9.42
1906–7	65.076	638,193	9.81

The actual cash gain by the Santa Fe below the Southern Pacific was $322,249; the unit gain, a fairer comparison for the Southern Pacific, $313,796. Had the cost per unit remained what it was in 1903–4, on the Santa Fe, the 1906–7 bill would have amounted to $666,315. The methods of Scientific Management should therefore be given credit for a reduction of $350,471.

Incidentally, the improvement in the condition and operation of the Santa Fe tools was very great.

I expatiate at length on this pecuniarily unimportant item, although it has tremendous dependent sequence effect on all shop repairs, because on the Santa Fe the reforms were carried out not by me, but by a staff expert selected by me and appointed by Mr. Kendrick for this particular work. At the time of his selection, June, 1904, he estimated the possible reductions at $200,000. At the end of two years, on the basis of same number of units, he had effected reductions of $179,573, at the end of three years of $253,909, at an expense in no year exceeding $10,000 for his services and those of all his assistants engaged on this work. This specialist did for tools exactly what Gen. Charles Miller did for lubrication: he bettered the quality, standardized conditions and operations, and everlastingly exercised helpful supervision.

The expenses incurred for new tools, charged to capital not included in maintenance account were as follows:

1904–5 TO 1906–7.

Santa Fe.	Southern Pacific.
$363,968	$765,169

Even these records do not comply with the requirements of Scientific Management. Happily there are others that strictly do comply.

In 1905 the efficiency organization began to determine standards of time for each different item of work. These standards of time were based on time and motion studies of particular men, of particular machines. These standards were called schedules, and altogether many thousand were prepared by men selected from the various trades, men trained and supervised by the efficiency staff. A combination was thus obtained of railroad experience with efficiency experience. These schedules covered just such items as those given in illustration by Mr. Symons—broken frames, cracked cylinders,[3] etc.:

The same schedules were in force for several years as to the same operations, in the same shop, on the same machines, run by the same men, under the same foremen. All conditions were therefore as strictly comparable as they could possibly be.

These schedules were practically so perfect that when used to predetermine the cost of the repairs to an individual locomotive coming to the shop the actual costs of repairs on one hundred locomotives only differed from the theoretical, predetermined repair costs by 4 per cent.

Efficiency of work under these schedules was determined by dividing for each man, each month, the standard time indicated on the schedules by the actual time he took to do the work. If, of three men in the shop, each present 250 hours in a given month, one turned out 200 hours of standard work, his efficiency was 80 per cent.; if the second turned out 250 hours, his efficiency was 100 per cent.; and if the third delivered 300 hours of standard time in 250 hours of actual time, his efficiency was 120 per cent.

The progress of the shop between January, 1905, and October, 1907, is shown in the table.

	No. of men	Standard hours	Actual hours	Efficiency per cent.
December, 1904	21	2,011.2	3,613.9	55.6
January, 1905	50	4,350.2	7,418.8	58.6
February, 1905	77	7,649.6	12,748.3	60.0
March. 1907	251	27,051.8	41,463.0	89.3
August, 1907	656	122,736.4	126,534.4	97.0
September, 1907	731	120,357.5	120,478.0	99.9
October, 1907	771	148,841.0	146,434.0	101.7

[3] Shop Betterment on the Santa Fe. H. W. Jacobs. John Wiley & Sons.

The effects of the application of efficiency principles to this shop, the largest on the Santa Fe system, were:

(1) To increase output enormously without adding to shop equipment or space.
(2) To reduce unit costs 30 per cent. or more.
(3) To increase the pay of the best men as much as 30 per cent. on the average.
(4) To hold permanently the best men.
(5) To know accurately the cost of every item before work is begun on it.

Relations of costs and efficiencies in a shop working 10,000 hours a day, average wages $0.36, average machine rate $0.40 per hour, average burden $0.24 per hour:

Efficiency	Increase in wages	Total cost per day	Reduction in unit cost	Increased output
60	0.	10,000	0.	0.
70	7.92	10,007.92	14.24	16.7
80	117.72	10,117.72	24.12	33.3
90	356.76	10,356.76	30.96	50.
100	720.	10,720	35.68	66.7
110	1080.	11,080	39.56	83.3
120	1444.	11,444	43.00	100.

A shop, as above, increasing its efficiency from 60 to 120 per cent., not impossible of realization, increases wages 44.4 per cent., decreases unit costs 43 per cent., and doubles the output. The actual realization was 101.7 per cent., showing a cost reduction of 36.33 per cent., an increased output of 69.5 per cent.

The work on the Santa Fe as to belting, tool maintenance, locomotive repairs forced upon us the appreciation of the universal law earlier applied to lubrication by Gen. Charles Miller: that when efficiency methods are applied costs go down.

High costs mean inefficiency; efficiency means low costs. It is inevitable. The efficiency staff therefore turned its attention to the establishment of standards. We made the most elaborate study of locomotive operation that has ever been made. For a period of five years we had the individual records of mileage, of fuel consumption, of repairs in round-houses and shops of 1500 locomotives of many different types under very different conditions of service. We did for locomotives what actuaries have done for life insurance. We used a unit of comparison taking into account both weight and mileage.

We determined beyond the slightest question that, on the average, Santa Fe locomotives could be maintained for $50 a year per unit, about $0.06 a mile for locomotives weighing 167,000 pounds on drivers and running 30,000 miles a year. At the time we began and before the strike the average was $96.63, or about $0.113 a mile; in 1907 the average was $72.60, about $0.094 a mile.

Certain passenger locomotives on the A., T. & S. F. have given 160,000 to 231,000 miles between the periods of general repair. Locomotive 1420[4] of the Albuquerque division up to June 10th, 1910, had been in service four years without shopping, had made 232,894 miles, was not due for shopping for two months, had an allotment for repairs of $0.059 a mile and an unexpended credit of $1500. Others of the same type show a performance of only 34,000 miles. Can anyone doubt that this average unsatisfactory performance is due to causes ultimately if not immediately preventable?

On any railroad the cost of locomotive repairs can be standardized and the predetermined standards can be realized, not by main strength, but solely through a combination of local experience and a plan applying all the efficiency principles.

In September, 1907, a final report was rendered to Mr. Kendrick showing how locomotive repair costs as to locomotives then in service could be reduced to $0.06 a mile, a figure averaged as to all the locomotives on several divisions.

The final report showed on what divisions standards had been attained and how, on what divisions they were not attained and why. The causes were numerous, but chiefly type of locomotive, ability of master mechanic, and character of service. Under the same master mechanic locomotives of different type in similar service varied 100 per cent. in repair cost; under different master mechanics, locomotives of the same design and class varied 100 per cent. in repair cost. Shop facilities had very little influence; old and poorly-equipped shops seemed to be able, when well directed, to repair locomotives as cheaply as the best-equipped shops of the system.

During the three years from April, 1904, to April, 1907, the

[4] *Railroad Age Gazette*, July, 1910.

efficiency staff, which had gradually increased to 30, were watching efficiencies everywhere. We watched other railroads and other railroad shops, we watched all branches of operation, we saw freight blockades which at small expense could have been mitigated. We saw the losses due to poor dispatching, to inefficient operation of all equipment, and, above all, we began to grasp the underlying laws that affect economy. We discovered why it was that tool maintenance could be reduced to one-third and belting purchased to 5 per cent. of what it had been.

The work on the Santa Fe, although only a beginning, only crude, was investigated, passed on, and endorsed by representatives of the *Railroad Gazette* and of the *American Engineer and Railroad Journal*, and also by the editor of the *Engineering Magazine*.

The first time attention was ever called to the million-dollar-a-day wastes and their cause was in a solicited article for the editors of the *Railway Age Gazette*.

The records as to economy on the A., T. & S. F. from 1903–4 to 1906–7 are not a matter of opinion. The facts appear in the annual statements of the president of the company, as well as in the sworn statements to the Interstate Commerce Commission. Nobody, least of all myself, ever maintained that the A., T. & S. F. had applied universally or thoroughly or widely the principles of efficiency. The most that was ever contended was that in the spots where they had been applied efficiency increased in the broadest sense, and costs decreased. Does close observation of railroad operations for thirty years, do fifteen years of experience in efficiency work, do the minute and careful investigations of railroad operations by a staff of many specialists not only for nearly four years on the Santa Fe, but also on a great number of other roads before and since, do the inevitable effects of dependent sequence to which railroads are peculiarly liable in their operation, justify the estimate of preventable losses of $2,000,000 a day?

The line of reasoning is:

(1) That the cost, supply, distribution, and use of materials by railroads is not essentially different from the cost, supply, distribution, and use of materials by other industrial concerns;

(2) That the cost, supply, distribution, and use of personal services by railroads is not essentially different from the cost, supply, distribution, and use of personal services by other industrial concerns;

(3) That the economical and efficient utilization of investment expenditures in cost, supply, distribution, and use is not essentially different in railroads from cost, supply, distribution, and use of similar charges in industrial plants.

Railroads manufacture transportation, they add to the value of products and individuals by carrying them from one point to another. We have only to compare railroad transportation as to speed, economy and safety with earlier means of transportation, as slave ships and caravans, to realize the astonishing absence of waste of railroad operation as to the particular function for which they were created.

Most plants show high efficiencies as to materials of manufacture, most plants show low efficiencies as to supplies for operation and maintenance. Railroad operation, if materials of manufacture are included, is on the whole very much superior to that of industrial plants, and if only supplies, labor and investment charges are considered railroads are still superior to most industrial plants.

Therefore as to every kind of plant, railroads included, there are three, and only three, main classes of expense—materials, labor, fixed charges.

	$525,000,000	+ $1,019,000,000	+ $1,210,000,000
Total Railroad Costs =	Supplies	+ Labor	+ Investment charges
Efficiencies	66.7	72.9	65

$$\text{Total Standard Railroad Costs} = Q\,P + T\,W + t\,R$$

$$\text{Total Actual Railroad Costs} = \frac{\text{Standard Costs}}{\text{Efficiencies}}$$

As to Supplies, as to Labor and as to Investment charges there are two elements—Quantity and Quality.

As to Supplies, we have quantity used and price per unit. As to labor, we have quantity of time required and price or wage rate per hour. As to fixed charges, we have quantity of time equipment is used and cost per hour.

Given a certain standard of excellence, Scientific Management asks that the product of quantity and price shall be a minimum; but hitherto, almost universally, price has been considered and not quality. It was Gen. Charles Miller's great merit that as to lubrication he has persuaded 98 per cent. of the railroads to consider quality rather than price.

It is not the price of material that counts, because it is very difficult to lower its price. It is the use made of it. In industrial operation, from whose laws railroads are not exempt, the prices or materials are fixed or rising. It would, for instance, have been very difficult for any railroad president to buy rails at less than $28 a ton. If, in fact, he wants better rails the price will be raised.

The only way to reduce the cost of rails is:

(1) Not to buy more rails than are needed. (Efficiency of supply.)

(2) Not to buy heavy rails where lighter rails would have answered just as well. (Efficiency of distribution.)

(3) To buy rails of such shape and quality, so to lay them and maintain the road-bed, so to design curves, grades, and wheel flanges as to cause minimum practical wear. (Efficiency of use.)

All these efficiencies are no doubt fully considered as to rails, whose renewals, after all, amount to a very small item of railroad maintenance expense; but what about stationery and other printed supplies (as time-tables), for which the aggregate bill is almost as large as for rail renewals?

Is the price per unit for printing as low as it ought to be?

I assume that it is.

Are more different time-tables and other forms printed than are needed?

The eminent purchasing agent of the Harriman lines is reported to have said that by standardizing forms he had been able to reduce printing bills 30 per cent. Are more time-tables and other forms distributed than are needed? We all know that hotel racks are filled up with time-tables obsolete before they are taken.

When it comes to use it is safe to say that in America, where time-tables are forced free on a traveller, he uses ten times as

many as in Europe, where he pays a cent or two cents for a time-table.

Therefore as to time tables, efficiency of price	100	per cent.
efficiency of supply	70	per cent.
efficiency of distribution	70	per cent.
efficiency of use	30	per cent.
End Efficiency	14.7	per cent.

Time-tables cost seven times as much as they might.

Innumerable other examples of inefficiencies of supply, distribution, and use could be given.

As Gen. Charles Miller, according to Mr. Symons, by Scientific Management secured a lubricating cost to the railroads of $21,000,000 which would otherwise have been $31,000,000, the reduction is about 33.3 per cent.

The total cost of all railroad supplies is $525,000,000, and, applying the same percentage, the possible reduction is $175,000,000. The average efficiency of railroad supplies may therefore be 66.7 per cent., the preventable loss may be $175,000,000.

I have seen loads of telephone poles bound to flat cars with heavy copper wire, the requisition having been made out by some busy foreman, put into the hands of an ignorant foreigner, carelessly filled by a division storekeeper. By analysis made by the test department chemist we found scrap metal containing 51 per cent. of tin being used to counterbalance locomotive drivers, tin at that time being worth $0.25 and lead $0.04. These are isolated cases, of course, but the dependent sequence is always busy somewhere, if not everywhere, with its deadly work.

Gen. Charles Miller increased the price of lubricating oil. Price efficiency sank from 100 per cent. to 70 per cent., but he furnished much less; it was not wasted before it was used, therefore efficiency of supply was brought up from 70 per cent. to 90 per cent. He distributed suitable oil, not cylinder oil, to freight cars and the efficiency of distribution rose from 60 per cent. to 90 per cent. He saw to it that very much less was used —in the words of Mr. Symons, "no umbrella was necessary, or Gospel measure"; the efficiency of use rose from 30 per cent. to 90 per cent. What is the end result?

$$\frac{QP}{70 \times 60 \times 30 \times 100} = \frac{QP}{12.6},$$

actual cost eight times what it ought to be, was changed to

$$\frac{QP}{90 \times 90 \times 90 \times 70} = \frac{QP}{51},$$

actual cost one-quarter of what it had been. Naturally, the cost to the railroads fell from $0.20 per 1000 miles to $0.06.

Lubricating oil is not a large item of railroad cost, about $21,000,000 for all the railroads in the United States. Coal, the largest item, is more than one-third of the total supply bill, costing $188,736,000 a year. The dependent sequences in coal are not four, but a dozen.

Excessive costs at the mine, due both to

(1) High price and
(2) Short weight deliverances;
(3) Losses in transit;
(4) Losses at the bunker;
(5) Losses in loading on to tender,
(6) Losses in round-house from wasteful and
(7) Premature firing up;
(8) Losses in firing owing to poor engineering;
(9) Losses in firing owing to poor stoking;
(10) Losses due to poor loading and
(11) Poor dispatching of trains;
(12) Losses in returning to round-house.

In various tests made as to freight, passenger, and switch locomotives, coal consumption has been found to be three times what care and supervision could reduce it to.

A recent practical demonstration of fuel economy is reported in detail in *American Engineer and Railroad Journal*, p. 439, 1911:

	Coal per passenger train mile	Coal per passenger car mile
Test Train 4, June 21, 1911....	67.33 pounds.	7.134 pounds.
Average 1910	132.2 pounds.	24.4 pounds.

If Mr. Symons's claim as to lubricating oil is extended to all supplies, the average efficiency is only 66.7 per cent., as to stationery, it is probably not over 30 per cent., as to coal, the

largest single item of supply expense, the efficiency is probably not over 50 per cent. Each item of supply can be separately investigated and an approximate efficiency be established. Many careful investigations and tests of this kind have been made and all the testimony lies in the direction of an average supply efficiency lower rather than higher than 66.7 per cent.

The same formula holds good as to the third great class of expenses, investment charges. Here, also, it is not cost of locomotives and cars, road and stations that counts, but oversupply, faulty distribution, and inadequate use. As locomotives spend nearly one-quarter of their lives in the shops for repairs, when an attainable standard might be 10 per cent. instead of 25 per cent., it is evident that the efficiency of supply is only 85 per cent. The natural inclination is to be extravagant. It is convenient to have a surplus of locomotive power; it is much easier to have extra locomotives for emergency service rather than assiduously to plan to use effectively a small number. The vice-president in charge of operation of one of America's greatest railroads told me that his ambition was to have in reserve for emergencies, for snow blockades, when tonnage has to be reduced, 100 locomotives, slushed and under cover. While not an efficient expenditure, it would have been less wasteful than the investment of $100,000,000 in a terminal nobody wants to use if he can avoid it.

The low mileage of American locomotives—27,000 miles a year, about 75 miles a day—indicates oversupply. A good team of Yukon dogs will go this distance in a day. A horse, if emergency arises, will temporarily exert eight times his normal power. Let us learn from dogs and horses how to maintain high averages and meet emergencies.

How often are large locomotives attached to small trains! (Inefficiency of distribution.) How often does it take twenty hours for a five-hour run! (Inefficiency of use.) Freight cars are no better. An average of only twenty-five miles a day, the distance that a postman walks daily. How often are small loads sent in large cars! To what extent do cars move slowly when they ought to run fast?

The same law applies to track. More miles than are needed, few trains per day using the track!

What shall we say of the paralleling of one road before the

first road has enough traffic to keep it busy? Why should the Northern Pacific have been paralleled from the Missouri River into Tacoma and Seattle, a distance of 1000 miles? Why should the Western Pacific have paralleled the Southern Pacific from Salt Lake City to San Francisco? Why should the New York Central have been paralleled from New York to Buffalo? About thirty years ago the Burlington paralleled the Northwestern up the Mississippi to St. Paul and Minneapolis. In Nebraska the North Western, in retaliation, paralleled the Burlington all through the counties of Southern Nebraska. Both roads were injured. Who can deny that there is a larger quantity of railroads than needed? The records of 1910 for the United States show 81 abandoned railroads. That so many of them fail to pay dividends further proves it. Let us call the efficiency of supply 90 per cent., the efficiency of distribution 90 per cent., and the efficiency of equipment use 80 per cent., and we have an end efficiency of 65 per cent. The total equipment charge per year on basis of present capitalization is about $1,210,000,000. Ought it on basis of present capitalized unit cost to have exceeded $786,500,000? Is not the loss that can ultimately be wiped out $423,500,000? This, added to the $175,000,000 of material waste, sums up to $598,500,000, or more than a million and a half a day.

A million and a half a day and I have not yet touched labor—labor that everybody is so worried about, except the heartless scientific managers; labor at whose expense all the saving of one million dollars a day was to be made; labor, always the first point of attack when reductions seem necessary. It is so easy to issue an order to reduce the payroll 20 per cent., to cut the wage rate, to lay off those who can least stand the strain, who have the smallest margin above misery!

Mr. Symons is very solicitous about labor, yet so ingrained is the virus of wage reduction that he estimates the total amount that could be saved by Scientific Management at $78,000 a day, about $23,400,000 a year, and he takes it all out of labor. Even as a railroad economist he is not a good guesser, for between 1908 and 1909 the railroads of the country reduced their payrolls $47,000,000, although apparently (so unreliable are the records) they employed 66,500 more men. The reduction in pay, as was to be expected, fell most heavily on those who were

least skilled, the classes of highest skill increasing either in number or in average daily pay.

To slash the payroll either by cutting rates of pay or laying off men is abhorrent to all Scientific Management, is contrary to all the principles of efficiency. Permanence of employment, higher skill, and higher pay are the aims of Scientific Management. Nevertheless, "Labor" is subject to exactly the same analysis as materials and equipment.

The cost of labor consists of two factors:

(1) Time used, corresponding to quantity, and

(2) Wage rate per hour, corresponding to price.

As to wages, man is not a machine. Continuous horse-power from Niagara costs about $20 per year. If men working at 66 per cent. efficiency and receiving $2 per day delivered a continuous horse-power for a year the cost would be $54,000 per horse-power. Man is not an animal. As a producer of energy the horse is cheaper than the man. It would take a man with a spade 560 seasons to turn up a section of prairie land, 640 acres. Directing a team dragging a plow the man can accomplish the work in four seasons, but with oil pull engines and gang plows twelve men will do the plowing in 36 hours.

Only a fool man will try to match his strength against animals and engines. Man can think, can supervise, can direct; animals and engines cannot. It is for directing intelligence that men are wanted and for which they will be paid. There is no limit to their upward value.

The general officers of railroads average $12.67 a day, trackmen only $1.38. Ten, a hundred, a thousand trackmen could not replace a great railroad executive. The average daily pay of all railroad employees, including presidents, seems to be $2.20. This is none too high. Wages can go up only as quality improves, and in the equation of T W, wages, W only rises as T, Time, falls, and T falls not by using muscle strenuously, but by using brain efficiently.

Labor expenses of the railroads aggregated, in 1909, $1,019,000,000 a year. As to labor, there is inefficiency of supply, inefficiency of distribution, and inefficiency of use. All these three inefficiencies occur in greater or less degree as to all classes of labor. There is inefficiency of supply when three men are employed to do the work of two men. If there are too many

locomotives and trains, there are inevitably too many locomotive crews and train crews. If any man does useless work, there is inefficiency of supply. If a high-priced man is put on low-priced work, work that could be done better by steam and machinery, there is inefficiency of distribution.

For three months one winter I watched a gang of 500 men at $6 a day shovelling snow on a railroad grade; they worked hard and they were none too many. The following winter the bread was theoretically taken out of their mouths by a rotary snow-plow.

I have seen a man take eighty times as long at a job as he ought to take. I have seen men spoil jobs that had to be done again. This is inefficiency of use.

Even as Gen. Charles Miller doubled the price of oil, improving its quality, but reduced operating costs by lessening its quantity, so again and again in railroad work and elsewhere we have found that as quality of labor improves, a higher rate per hour being paid, quantity of time required goes down.

Nobody pretends that lubricating oil works any harder than twenty years ago; it works more efficiently. At the Topeka shops some men earned 100 per cent. above wages for a whole year. They did for themselves what General Miller did for his oil. They cut out the wastes because they were higher-quality men, and because they were higher-quality men they doubled their wages per hour.

The principle of price and quantity applies from the president's chair down to the Mexican on the grade. No class of worker is exempt. Some men hold more important positions than others, some men in comparatively humble positions are able immensely to waste or to save. We have checked over every class of railroad labor and find as to all classes the dependent sequences of rate, of supply, of distribution, and of use. Mr. Symons's sweeping exclusion of all classes except shopmen is astounding. In what way do railroad clerks differ from other clerks, railroad trackmen differ from other handlers of dirt and wood and iron? In centralized, supervised, repeated work the efficiencies of the dependent sequences ought to be high. In decentralized, unsupervised, unrepeated work, just such work as constitutes track maintenance, the efficiencies of the dependent sequences are low, terrifically low, and when the attention of a

general manager was called to their existence his only excuse for the large force was that he held all these men through spring, summer, and autumn because he might have a snow blockade in the winter. The fear of snow blockade did not prevent another Western road from reducing its section men to one for each eight miles when economies were imperative to impress Wall Street.

Labor on a whole ranks better than materials; by test of each different class, summarized for all classes, it averages below 80 per cent. The rate per hour varies much for men of the same grade in different parts of the country, much more for men in different classes. The inefficiencies are high wherever the pay is low.

Wages are often high where the cost of living is cheap, wages often low where the cost of living is high. One class is high in the East and low in the West. I justly debit to labor or personal service expenses the peculations and steals that have occurred. The one steal of $623,000 on the Big Four enhanced the payroll of that system $2000 a day for a whole year. The several-million-dollar steal on the Illinois Central enhanced the payroll of general officers $7500 a day for two years. Both these steals would have been impossible under Scientific Management.

Let us, however, not quarrel with the rate per hour, as this usually indicates quality. Attention is to be directed to the great inefficiency of work distribution, to the great surplus of time, and to the great inefficiency of time use. In all but the most highly organized industrial plants the efficiency of supply is not over 80 per cent., the efficiency of distribution is not over 80 per cent., the efficiency of use is not over 80 per cent. This gives us an average end efficiency of 51.2 per cent.

Before going to the rate hearing we checked up the piece rates for the identical operation of turning up Pullman wheel tires and found it to vary from $0.28 to $1.40. The men on different rates earned daily about the same wages, yet the time efficiency of the $1.40 rate men was only 25 per cent.

Many of the railroads boast of their piece rates. Piece rates are not an efficiency proposition. They are based on the theory that they will promote strenuousness; but strenuousness is opposed to efficiency, which works on the theory that intelligence, not toil, produces best results.

I know of no class of railroad labor as high as 90 per cent. in each term of the sequence. I have known literally thousands of cases in all classes of railroad work where one or the other term was below 60 per cent.

Assuming, however, 90 per cent. as to each term of the sequence, the end efficiency is 72.9, and as to $1,019,000,000 the preventable loss is $275,000,000. One-half of this should go to increasing the rates of pay in order to secure better quality. This reduces the possible saving to $137,500,000. Add this to $175,000,000 estimated loss on supplies, $423,000,000 estimated excess in investment charges and we have a total of $736,000,000, or over $2,000,000 a day for each day in the year, even if it is leap year.

Even with supreme wisdom, or even such wisdom as Germany brings to bear on her industrial problems, it would take time to eliminate all this loss. The $175,000,000 as to materials could be remedied in a very short time, say five years.

The loss in personal service efficiency, less than one-quarter of the total loss, only $137,500,000 could be eliminated in ten years, by educating the workers, including general officers, to greater efficiency, by employing more men who think and fewer who merely toil, by standardizing conditions so that efficiency would be easier and there would be no necessity to discharge a single man. On the contrary many poorly qualified men would have to be engaged to replace those dropping out from natural causes.

But as to investment, with proper backing by the United States Government and a suitable amortization of capital $423,500,000 a year could be wiped out in forty years.

There are a number of eminent efficiency engineers in the country. There are also a number of executives. There are a number of labor leaders. Instead of giving the lie to each other, why not put the matter to a test?

An American Society for Promoting Efficiency is forming. The object of the society is to promote efficiency in enterprises of all kinds, including public service corporations. A special committee working to establish definite standards will be formed.

Under the auspices of this society competent efficiency specialists, at small, perhaps even no expense to the railroad companies, could investigate any representative item of cost on any railroad in the United States, report on actual methods in use,

and also outline scientific control of the cost of the same item, showing the difference between what is and what might be.

If this opportunity should be used, if the investigation should show worth-while economies, the next step ought to be to carry the economies into effect and to that end railroad men, efficiency engineers and labor leaders ought to co-operate so that the railroad managers may be convinced that high efficiency means better operation at less cost, that labor men may be convinced that high efficiency means a higher manhood, less toil and higher pay.

Incandescent Gas-Mantles. ANON. (*Eng.*, cii, 2381, 238.)—Some time ago it was discovered that ramie was much more effective than cotton for the construction of incandescent gas-mantles, because the separate fabric of the yarn employed remains fairly wide apart and presents a larger glowing surface, which led to an increased lamp efficiency. According to the *Journal of the Royal Society of Arts*, experiments with artificial silk show that the fibres of this material maintain their individuality to an even greater extent than ramie, and the mantles themselves are said to be much more elastic, supple, and durable. The *Deutsche Gasglühlicht Company* of Berlin intends shortly to place a new artificial silk mantle on the market.

New Petroleum Fields in Turkestan. ANON. (*Eng.*, xcii, 2381, 227.)—Prof. Hjalmar Sjögren, the Swedish scientist, has completed a survey of the petroleum springs in Turkestan. These springs cover a vast area which extends to the Chinese frontier and the Pamir plateau. It is believed that the new springs will not revolutionize the petroleum market, but probably will be able to supply the ever-increasing requirements of large surrounding districts; for instance, China is becoming a large consumer. Indirectly, therefore, the new springs may benefit European consumers. Professor Sjögren has not yet finished his investigation, and expects to visit Turkestan again in a short time.

Casein Manufacture in Australia. ANON. (*Ch. of Commerce Jr.*, Nov., 1911.)—A factory for the manufacture of casein will be established at Lismore, in New South Wales. While the factory proper will be at Lismore, precipitating stations will be established wherever a supply of from 2,000 to 3,000 gallons of skimmed milk can be obtained. At these stations the casein will be separated from the whey, and forwarded to the head factory for final treatment. The price paid to the farmers will, it is estimated, be 100 per cent. increase on the value of the skimmed milk as pig feed.

FRANKLIN INSTITUTE

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 17, 1912.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 3.

The tellers, Messrs. Colvin, Cullen, and Jennings, submitted the report of the ballots cast for President, two Vice-Presidents, Treasurer, and eight members of the Board of Managers.

The following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

James M. Dodge, Vice-President (to serve three years).

Coleman Sellers, Jr., Vice-President (to serve two years).

Cyrus Borgner, Treasurer (to serve one year).

Charles Day, John J. Gibson, George A. Hoadley. George E. Kirkpatrick, Isaac Norris, Jr., Lawrence T. Paul, James S. Rogers, Otto C. Wolf, Managers (to serve three years).

The President presented a statement of the work of the Institute during the past year.

Following the meeting of the Institute for the transaction of this business a joint meeting was held with the Philadelphia Section of the American Institute of Electrical Engineers. The President called upon Mr. H. Clyde Snook, chairman of the Philadelphia Section A. I. E. E., to take the chair.

In taking the chair, Mr. Snook spoke as follows:

"I take the liberty, on behalf of the American Institute of Electrical Engineers, to extend to the President of the Franklin Institute our congratulations upon his long and faithful service for the Franklin Institute, and to wish him well as he now enters upon another year of active and interesting work.

"The Philadelphia Section also congratulates the Franklin Institute upon its present and renewed activity. The life of the Institute is quickened more than it was last year. Each year seems to be, as it should be, an improvement over the preceding year.

"This evening, to each one of us who is fortunate enough to be present, is presented another example of what can be accomplished by co-operation in the advancement of the efficiency of the electrical engineer and of engineering in general.

"To-night we have a joint meeting of the Franklin Institute and the American Institute of Electrical Engineers. We have co-operation, not only between these two scientific bodies, but also the co-operation of all of the engineers who are present, and the co-operation of one of our largest

industrial organizations, which has complimented us to the extent of permitting the head of its research laboratory to come and tell us something of the work they are doing, and about which you could not otherwise learn if you spent thousands of dollars in money and thousands of hours of time, and travelled thousands of miles of space. This emphasizes the fact that failure to attend these meetings means that you miss things which might be brought to bear to increase your efficiency."

He then introduced Dr. W. R. Whitney, director of the research laboratory, General Electrical Company, Schenectady, N. Y., who presented a communication entitled "Research Laboratory Notes."

The first subject considered by the speaker was the manufacture of brushes for electric motors. The requirements of a brush were pointed out and the numerous experiments made with a view to its development were fully described.

The vacuum in incandescent lamps was next brought to the attention of the meeting. The various methods of producing a vacuum and the effect of a partial exhaustion of the air from lamp bulbs were considered.

A detailed account of the various departments of the laboratory of the General Electric Company was next given. The paper was illustrated by lantern slides.

The following gentlemen took part in the discussion of the paper: Messrs. J. C. Ramsburg, George R. Green, C. O. Bond, Dr. George A. Hoadley, Messrs. James M. Dodge, Frank B. Gilbreth, and others.

The chairman called on Dr. Hoadley, who presented a memorial minute upon the death of Mr. Charles R. Young. On motion, duly seconded, the resolution was unanimously adopted.

President Clark then resumed the chair. On motion, duly seconded, the thanks of the Institute were extended to Dr. Whitney for his interesting paper.

Mr. W. N. Jennings then exhibited and described six views of the recent disastrous fire on Market Street, showing the remarkable ice formations on the ruins.

Adjourned.

R. B. OWENS,
Secretary.

REPORT OF THE BOARD OF MANAGERS FOR THE YEAR ENDING SEPTEMBER 30, 1911, WITH APPENDICES EMBRACING THE ANNUAL REPORTS OF THE VARIOUS COMMITTEES AND SECTIONS.

To the Members of the Franklin Institute:

For the sixth time I have to thank the members of the Franklin Institute for entrusting to me the duty of presiding at their meetings, and assisting, as president, in the conduct of the affairs of this venerable association.

I think that each year I appreciate more the honor thus given me, as I

know that each year I enjoy more the performance of the interesting duties you have laid upon me.

The reports of the standing committees for the year past have been printed and are now in the hands of the members. I hope they will convince you that the work of the Institute, so far from being permitted to lag, has been pushed with increased vigor.

During the past year the Library facilities have been so extended that the books are more readily available than heretofore to the use of the student and the investigator. Our schools, through a greatly enlarged number of students, and through improved methods, have added to their usefulness in the industrial education of the youth of the community.

There has been a gratifying increase in the size of the audiences attracted to our meetings. Not infrequently our time-honored hall is taxed to its capacity. Printed in the JOURNAL, the valuable subject matter presented at these meetings, and other communications of great technical interest, have evidenced, in this country and abroad, that it, America's oldest scientific journal, retains unimpaired its characteristics of originality and leadership.

I was compelled to report to you a year ago that the finances of the Institute were in an unsatisfactory, though in an improving, condition. I am able to-night to report that the financial condition has been greatly improved. Through the generosity of our late active member, Mr. John H. Noblit, now deceased, and through the desire of his brother, Mr. Joseph C. Noblit, to arrange that the Franklin Institute should at once have the benefit of a legacy that otherwise would not, probably, have come to it for many years, we have, within the last two months, added to our Endowment Fund approximately $135,000—yielding an annual revenue of something over $6,400. The Institute is thus indebted to Mr. John H. Noblit, deceased, whose memory we hold in honor, and to Mr. Joseph C. Noblit, now still and fortunately living, for this large and welcome addition to its resources.

We have also received, during the past year, through the generosity of Miss Maria Blanchard, deceased, and the good will of her sister, Miss Harriet Blanchard, a legacy of $10,000—adding nearly $500 a year to the income of the Institute.

Appropriate resolutions commemorative of these deeds of generosity are now being prepared by a committee of the Board of Managers.

The Franklin Building Fund grows slowly. It is probable that we will not be able to do anything this year toward the erection of the hoped-for new building for the occupancy of the Institute. In the meantime, the work of the Institute is meeting the approval of the scientific world, and it is the determination of the officers and managers, to whom you have entrusted the conduct of its affairs, to hand our institution on to their successors unimpaired in its record and undiminished in its honor.

For the Board of Managers.

WALTON CLARK,
President.

PHILADELPHIA, January 17, 1912.

REPORT OF THE COMMITTEE ON INSTRUCTION

To the Board of Managers:

The Committee on Instruction reports as follows:

The work of the school during the eighty-seventh year, ending September 30, 1911, was again carried out on the lines laid down in the summer of 1909, under the directorship of Mr. William H. Thorne, Professor of Drawing, with the assistance of the following officers of instruction: H. E. Hutchins, Assistant Director, Professor of Mechanics; H. P. Tyson, Professor of Mathematics; M. H. Keil,* Professor of Naval Architecture; Clement Remington, I. V. Pedrick, A. V. McConnell, Instructors in Drawing; John Burt, William E. Bullock, Instructors in Mechanics; G. T. Sharp, Instructor in Mathematics.

The following table shows the registration in the various departments and also, for comparison, the corresponding registration in the preceding year:

Department.	Winter, 1909.	Winter, 1910.	Spring, 1910.	Spring, 1911.
Drawing	98	140	67	112
Mathematics	41	37	18	29
Mechanics	22	24	18	21
Naval Architecture	12	5	8	5
	173	206	111	167

A marked increase in number of students is shown in the Department of Drawing, an increase of 70 per cent. in the spring term. The aggregate registration in the other departments was also 121 for the year, as compared with 119 for the preceding year.

In the winter term of 1911–12 provision was made for the office to be open to prospective students for information and registration during the week previous to the commencement of the term, with the result that 90 students were during that week registered in the Department of Drawing, 42 in Mathematics, 22 in Mechanics, and 17 in Naval Architecture, indicating prospects for a good year.

The 1911–12 catalogue was drawn up on the lines of the previous issue, with the addition of a historical note on the work of the schools, a time-schedule of classes, and a sample of work done in the Drawing School, etc.

The following popular lectures were delivered in the hall of the Institute during the year, on the dates given:

December 9, 1910.

"Contributions of Photography to our Knowledge of the Stellar Universe." (Dr. John A. Brashear.)

*Succeeded by Prof. H. C. Towle in January, 1911.

December 16, 1910.
"Some Practical Observations in Alaska." (Mr. Edward R. Taylor.)
January 6, 1911.
"The Panama Canal." (Mr. William M. Ridpath.)
January 27, 1911.
"Some New Discoveries in the Development, Construction, and Dynamics of Language." (Mr. Hudson Maxim.)
February 17, 1911.
"In the Land of Manana, Under the Southern Cross." (Mr. W. N. Jennings and Mr. Charles K. Stokes.)

All the above lectures were exceptionally well attended; in fact, at some of them the seating capacity of the hall was quite inadequate.

Respectfully submitted,

LAWRENCE T. PAUL,
Chairman.

PHILADELPHIA, January 10, 1912.

REPORT OF COMMITTEE ON ELECTIONS AND RESIGNATIONS OF MEMBERS.

To the Board of Managers:

During the fiscal year (October, 1910, to September, 1911, inclusive) there were elected to membership:

28 Resident Members,
15 Non-Resident Members,
5 Associate Members,
4 Life Members.

During the same period there were resignations from:

12 Resident Members,
12 Non-Resident Members.

Deaths were recorded of:

16 Resident Members,
5 Non-Resident Members,
9 Life Members.

Respectfully submitted,

W. C. L. EGLIN,
Chairman.

PHILADELPHIA, January 10, 1912.

REPORT OF THE COMMITTEE ON STOCKS AND FINANCE FOR THE YEAR 1911.

Financial Statement, October 1, 1910, to September 30, 1911.

PROPERTY AND FUNDS.

Building and land, 13–17 S. Seventh Street	$60,000.00	
Library	100,000.00	$160,000.00

	Principal.	Unexpended income.	
Funds held by Board of Trustees	$65,167.10	$638.93	
Funds held by Board of Managers	23,478.50	407.98	
Franklin Institute Building Fund	351,428.60		
Elliott Cresson Medal Fund	1,000.00	2897.18	
Franklin Fund and Building Committee	4,282.50		
Total funds	$445,356.77	$3,944.09	449,300.86
Grand total			$609,300.86

LIABILITIES.

Certificates of stock	$30,430.00
Mortgage on Institute Building (held by Trustees as investment for funds)	2,825.00
Bills payable	28,250.00
Life memberships	2,185.00
Accounts payable	2,806.63
Unearned income	1,001.03
Grand total	$67,497.66

INCOME AND EXPENSES APPLICABLE TO YEAR ENDING SEPTEMBER 30.

Income.

Dues			$8,899.58
Donations			1,700.00
Initiation fees			70.00
General Endowment Fund			2,248.73
Estate of John Turner			119.29
Estate of Robert Wright			2,201.41
Membership badges			6.80
Instruction: Drawing		$1,231.50	
Mathematics		326.50	
Mechanics		223.00	
Naval architecture		75.00	1,856.00
Publications: Subscriptions and sales			1,689.21
Advertising			3,394.10
Total			$22,697.07

Expenses.

Building: Wages		$953.25	
Repairs and maintenance		677.36	
Heat, light and power		685.89	
Taxes, water rent and insurance		445.20	
Miscellaneous supplies and expense		386.55	$3,148.25

Elections and resignations		514.76
Instruction: Drawing	$1013.80	
Mathematics	238.40	
Mechanics	401.50	
Naval architecture	133.50	
Miscellaneous expense	466.01	2,253.21
Library: Salaries	$3200.86	
Books and periodicals	1745.94	
Binding	416.50	
Miscellaneous expense	297.55	5,660.85
Meetings		410.17
Office and General: Salaries	$7032.10	
Office expense	752.82	
General expense	1088.37	8,873.29
Publications: Printing	$3894.98	
Reprints	462.83	
Illustrating	408.56	
Miscellaneous expense	736.71	5,503.08
Science and Arts		1,146.44
Sections		669.45
Interest and discount		975.46
Special repairs		182.04
Interest paid John T. Kille on donation to General Endowment Fund		200.00
Total		$29,537.00
Net expense		6,839.93

During the fiscal year the General Endowment Fund has been increased by $1,850. The Franklin Institute Building Fund has been increased by $10,000 through interest accretions. Certificates of First-Class Stock have decreased by $780. The mortgage on the Institute building has been reduced by $750.

Excess of expenses over income for the year was $6,839.93. This deficit was, as last year, entirely due to outlays absolutely necessary in order to continue the rehabilitation of the Institute. The result of these outlays is evident from the increased attendance at the various meetings of the Institute and in other evidences of the revival of public interest in the work done by the Institute.

Respectfully submitted,

WALTON FORSTALL,
Chairman.

PHILADELPHIA, January 10, 1912.

REPORT OF THE COMMITTEE ON PUBLICATIONS.

To the Board of Managers:

The publications of the Institute, particularly its monthly JOURNAL and the reprints of individual articles therein, have expanded in volume during the past year in natural sequence to the widening scope of scientific work that has come to be centred here. The prevailing activity in the field of analytical research, both in the collecting of purely theoretical data and also the practical application of such data in the advancement of the arts, finds in the organization of the Institute potent means for its furtherance and in the JOURNAL OF THE INSTITUTE a universally recognized medium of publicity.

The amount of material of importance brought under consideration at the meetings of the Institute and of its several Sections has of late been rapidly increasing, as also have the number of announcements and reports sent in from authoritative investigators in various fields of work. We have thus had presented to us the necessity of increasing each issue of the JOURNAL by a minimum of sixteen pages, or the alternative of failing to do justice not only to our valued contributors but also to our membership-at-large. Your committee has chosen the former course as the only proper one under the circumstances. The cost of producing the JOURNAL, the requisite reprints, and the incidentals has consequently increased considerably during the year, but the earnings of the publication have almost kept pace with it. The fiscal year ended with a debit balance against the JOURNAL amounting to $419.17, a sum much less than the deficits of previous years, when the publication was run on a smaller scale and when its editions were not nearly so large as now.

The system of awarding the Howard N. Potts Gold Medal and of several Edward Longstreth Medals of Merit in recognition of the most important contributions to the JOURNAL, inaugurated last year, has afforded the Institute, through your committee, a means of testifying to the authors an appreciation which could not otherwise be adequately expressed. That these awards have been accepted in the spirit in which they were made may well go without saying. The idea has commended itself from every point of view, and not the least of its favorable aspects is that the awards are made through the medium of the Committee on Science and the Arts, to whose co-operation in this direction the Editorial Committee is greatly indebted.

Respectfully submitted,

LOUIS E. LEVY,
Chairman.

PHILADELPHIA, January 10, 1912.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS.

(Abstract.)

To the Board of Managers:

During the year ending September 30, 1911, thirty-one meetings were held by the Sections, and papers on the following subjects were presented:

PHYSICS AND CHEMISTRY SECTION.

Seven Meetings.

November 3, 1911.
The Theory of Problems in Chemistry. (Mr. J. T. Baker.)

December 22, 1910.
Recent Progress in the Chemistry of the Terpenes and Camphors. (Mr. Joseph S. Hepburn.)

January 5, 1911.
The Preparation and Testing of Drugs. (Prof. William A. Pearson.)

January 26, 1911.
Use of Lantern Slides in the Teaching of Chemistry. (Dr. Harry F. Keller.)

February 16, 1911.
Modern Commercial Food Manufacturing. (Mr. L. S. Dow.)

March 30, 1911.
Materials Used in the Manufacture of Paints. (Mr. G. B. Heckel.)

May 4, 1911.
The Teaching of Elementary Chemistry. (Dr. R. H. Bradbury.)

ELECTRICAL SECTION.

Seven Meetings.

October 6, 1910.
Some Recent Problems in Storage Battery Engineering. (Mr. Joseph Appleton.)

December 29, 1910.
Arc Lamps. (Mr. K. A. Albrecht.)

January 3, 1911.
The New Iron-Clad Exide Battery for Electric Vehicles. (Mr. E. H. Flanders.)

January 12, 1911.
New Metallic Filament Lamps. (Mr. G. S. Merrill.)

February 2, 1911.
Prepayment Electric Meters. (Mr. F. G. Vaughen.)

March 2, 1911.
Some Unexplored Electrical Fields. (Dr. Chas. P. Steinmetz.)

April 20, 1911.
Electric Furnaces. (Mr. Carl Hering.)

MECHANICAL AND ENGINEERING SECTION.

Nine Meetings.

October 13, 1910.
Mechanical Engineering Problems in Illuminating Gas Works. (Mr. James A. P. Crisfield.)

November 10, 1910.
Production of Power. (Dr. D. S. Jacobus.)

November 17, 1910.
The Air Brake as Related to Progress in Locomotion. (Mr. Walter V. Turner.)

December 15, 1910.
The Work of the Bureau of Standards in Connection with Structural Material. (Dr. S. W. Stratton.)

February 23, 1911.
Natural and Artificial Draft. (Mr. Henry G. Brinckerhoff.)

March 16, 1911.
Conservation of Iron. (Dr. Allerton S. Cushman.)

April 6, 1911.
Small Public Service Properties and Their Future. (Mr. W. S. Barstow.)

May 11, 1911.
Metering Steam and Gas. (Prof. Carl C. Thomas.)

May 18, 1911.
Machine Molding. (Mr. Wilfred Lewis.)

PHOTOGRAPHIC SECTION.

Four Meetings.

October 27, 1910.
Organic and Inorganic Forms Shown with the Projection Microscope. (Dr. Henry Leffmann.)

December 8, 1910.
A New Aero Camera. (Mr. W. N. Jennings.) Landscape Views. (Mr. Richard Pertuch.) Miscellaneous Lantern Slides. (Dr. Henry Leffmann.)

March 9, 1911.
Some Unusual Photographic Processes. (Dr. Henry Leffmann.)

April 13, 1911.
Review of Work of Section. (Dr. Henry Leffmann.) Lantern Views of Lightning. (Mr. John M. Justice.)

MINING AND METALLURGICAL SECTION.

Four Meetings.

October 20, 1910.

Selection and Treatment of Alloy Steels for Automobiles. (Mr. Henry Souther.) Address of the President of the Section: "Integrity of Tests of Metals." (Professor A. E. Outerbridge, Jr.)

December 1, 1910.

A Vacation Trip in Scandinavia with Some Observations on the Electrometallurgy of Iron and Steel. (Dr. Joseph W. Richards.)

February 9, 1910.

Eleventh International Geological Congress. (Dr. Edgar T. Wherry.)

March 23, 1911.

Vanadium Alloys. (Mr. George L. Norris.)

The increased attendance at meetings of all sections indicated a marked interest in the subjects presented.

Respectfully submitted,

R. B. OWENS,
Secretary.

PHILADELPHIA, January 10, 1912.

REPORT OF THE COMMITTEE ON ENDOWMENT.

To the Board of Managers:

Your committee reports that, while there were no endowments to record for the fiscal year ending September 30, 1911, covered by this report, since that date the sum of $145,822.79 has been added to the Endowment Fund of the Franklin Institute; the sum having been transferred by the Board of Managers to the Board of Trustees, and the interest of which is to be used by the Institute for maintenance. Of this amount the sum of $135,822.79 was received from the estate of the late John H. Noblit, of Philadelphia, and the sum of $10,000.00 was received from the estate of Miss Maria Blanchard, also of this city.

The Endowment Committee wishes to bring the Endowment Fund to the attention of the members of the Institute, as it is essential that a suitable endowment fund be provided not only for immediate use of the Institute, but for its use when it moves into a new building, which will necessarily entail additional expense for maintaining and carrying on the work on a greater scale. While a new building is essential, the endowment for the support of the new building is equally essential.

Very respectfully,

[Signed] HENRY HOWSON,
Chairman.

PHILADELPHIA, January 10, 1912.

REPORT OF THE COMMITTEE ON LIBRARY.

(Abstract.)

To the President and Members of the Franklin Institute:

The Committee on Library respectfully submits the following report on the activities of the Library during the twelve months ending September 30, 1911:

The additions to the Library during this period were as follows:

Source.	Bound volumes.	Unbound volumes.	Pamphlets.	Maps.
Gift	385	363	712	2
Journal	21	20	59	
Exchange	28		1	
Institute Appropriation	18	21		
Lea Fund	25	8		
Moore Fund	156	30	5	
Morris Fund	30	3	1	
Potts Fund	14	5		
Binding: Institute Appropriation	86			
" Chemical Periodicals Binding Fund	42			
" Moore Fund	4			
" Morris Fund	61			
	870	450	778	2

Total additions for the year, 2,100.

Gifts of books, periodicals, and pamphlets in larger quantities or of special value were received from Messrs. Hugo Bilgram, John E. Carter, George S. Cullen, Morris Ebert, S. E. Fairchild, Richard Gilpin, Carl Hering, Robert D. Jenks, Louis E. Levy, John McDowell, Richard Waln Meirs, Henry Pemberton, Jr., Drs. S. Solis Cohen, Samuel C. Hooker, Harry F. Keller, Wm. H. Trueman, Miss Wood, Mrs. Stuart E. Freeman, Mrs. Joseph Richards, Messrs. Cornell & Matthews and Harris & Richards, the Comptroller-General of Patents of Great Britain, the Royal Technical High School of Munich, and the Pennsylvania State Library.

The transfer of the non-technical documents to the Free Library, which was begun in September, 1909, has been finished. 466 volumes of the United States Government publications and 700 volumes of State publications were thus disposed of.

The removal of popular magazines was begun during the past year, and 228 bound volumes, 766 unbound volumes, and 11,047 numbers were sent to the Free Library. The greater part of this work is finished.

Five volumes on Scotland were deposited with the St. Andrew's Society of Philadelphia, in addition to those of which the deposit was reported last year.

The contents of the Library on October 1, 1911, after deducting the vol-

umes transferred to the Public Library and pamphlets bound, were as follows:

Volumes, bound and unbound	61,481
Pamphlets	47,613
Maps and charts	2,269
Drawings, designs, lithographs	783
Photographs	1,312
Newspaper clippings	192
Manuscripts	34

BINDING.

The total number of volumes bound during the year was 334, consisting of periodicals, patent specifications, unbound books and pamphlets.

BUILDING AND BOOK REARRANGEMENTS.

Numerous alterations and improvements in the building and in the interest of the Library, which were in progress at the beginning of the year, have been completed.

The transfer of the Actuary's office to the first floor and the use by the Librarian of the room thus vacated has provided the latter with office surroundings conducive to efficient work, and, at the same time, has relieved the library and reading-room from the noises and interruptions incident to the business of the Actuary's office.

The work of putting in order the many files of periodicals transferred from different parts of the building to the new periodical room in the basement is steadily progressing. The limited number of assistants in the library makes it impossible to push this work more vigorously; for the regular duties of these assistants occupy their time during the day, and this special work can only be taken up in the evening. The work of arranging the books in the room on the third floor is also only partly completed.

The model-cases in the reading-room have been rearranged so as to make it possible to utilize them for placing on view a number of the more important books of reference. The latter are now easily accessible, and it is hoped will be used more freely than heretofore.

The reading-room has been thoroughly cleaned up, newly painted and lighted, and new chairs have been added to its equipment.

Little more remains to be done in the removal of non-technical material and public documents. In the final rearrangement of all the classes may be found a small residue of books which is of no value in the Institute's collection, and which will be disposed of by sending it to the Free Library.

BINDING OF PAMPHLETS.

The binding of pamphlets on Mechanics has been continued during the year. In all, sixty volumes, containing over 600 pamphlets, have been bound. Eighteen of these volumes, or 170 pamphlets, have been fully catalogued, a total of three hundred cards being written. Forty-three volumes, approximately 400 pamphlets, are still uncatalogued. Other volumes are at the

bindery, and will soon be returned. To make these pamphlets fully available each one must be treated as a separate work, *i.e.*, making an entry for each under the author and subject, and, if advantageous, under the title.

BOOK PLATES.

During the year new book plates were provided for the Moore Fund, the Morris Fund, and the Potts Fund. The committee takes this opportunity to express to Mr. Louis E. Levy its appreciation of the care he bestowed upon supervising the preparation of the designs and the making of the half-tone blocks.

LIBRARY NEEDS.

Among the urgent needs of the Library none, perhaps, is more imperative than a special fund or appropriation for the binding of the enormous mass of books and periodicals that has accumulated. These unbound materials may be roughly classified as follows:

British patent specifications	2,840 volumes
British patent abridgments	250 volumes
Swiss patent specifications	350 volumes
Austrian patent specifications	247 volumes
Unbound volumes in the Library	10,426 volumes
Unbound periodicals	5,950 volumes
Total	20,063 volumes

The cost of binding is estimated at approximately $1 per volume.

In addition to the above, there is still the collection of pamphlets to consider; they should be either bound or otherwise provided for. A fund for the binding of pamphlets on chemical and electrical subjects is much to be desired.

Of even greater importance, in the committee's opinion, is the preparation of a complete statement of the condition of the periodical sets in the Library. This should afford full information as to the beginning of each serial, date of publication, number of volumes, whether bound or unbound, whether complete or incomplete, and, if incomplete, the enumeration of the missing parts.

There are now some 1,500 periodical sets on the library shelves, not including State publications. A statement such as the one here proposed would make it possible for the committee gradually to fill the gaps by supplying periodical dealers with lists of the Library's wants, and in carefully watching the lists published by such dealers. Although it is difficult to make an estimate of the time that would be required to make such an inventory, it is certain that this task can not be properly accomplished unless it receives the undivided attention of a trained librarian for a period of several months at least.

Respectfully submitted,

HARRY F. KELLER,
Chairman.

PHILADELPHIA, January 10, 1912.

REPORT OF THE COMMITTEE ON MUSEUMS.

To the President and Members of the Franklin Institute:

The Committee on Museums begs to report that during the year much work has been done in the way of rearranging the models in possession of the Institute, rendering them more serviceable to the student and investigator. Among others, the following interesting models have been thoroughly overhauled:

Model of Stephenson Locomotive, 1816.

Model of Oliver Evans's "Oructor Amphibolis" (the first American locomotive).

Model of Early Duplex Pump.

Model of Beam Engine, said to be the first engine at Fairmount Water Works.

Model of Early Horizontal Stationary Engine.

Static Electric Machine.

Stair Lift Model, Link-Belt Company.

Portable Engine.

Work is now being done on the revising of the classification of all the models, and for instruction purposes several have been transferred to the school-rooms.

Respectfully submiteed,

ALEX. E. OUTERBRIDGE, JR.,
Chairman.

PHILADELPHIA, January 10, 1912.

REPORT OF THE COMMITTEE ON MEETINGS.

(Abstract.)

To the President and Members of the Franklin Institute:

During the year ending September 30, 1911, ten Stated Meetings of the Institute were held under arrangements made by the Committee on Meetings, with the co-operation of the Secretary's Office. At these the following subjects were presented:

October, 1910: "Recent Advances in the Construction of Fire- and Burglar-Proof Safes." (Mr. E. E. Watson.)

November, 1910: "Mechanical Flight." (Mr. Geo. A. Richardson.)

December, 1910: "Applications of Chemistry to Public Welfare." (Dr. Harvey W. Wiley.) "The Technology and Application of Pigments." (Mr. Henry A. Gardner.)

January, 1911: "Water Filtration for Industrial Purposes." (Mr. Churchill Hungerford.)

February, 1911: (adjourned to Engineers' Club) "Panama Canal." (Col. Geo. W. Goethals.)

March, 1911: "Recent Astronomical Photography." (Prof. Geo. W. Ritchey.)

April, 1911: "Engineering as Related to the Structure of the Body Politic." (Mr. J. C. Trautwine, Jr.)

May, 1911: "The Handling, Transportation, and Storage of Perishable Foodstuffs." (Mr. Joseph S. Hepburn.)

June, 1911: No paper.

September, 1911: "Modern Uses and Applications of Radium." (Dr. Hugo Lieber.)

A good attendance at all meetings indicated a marked interest in all subjects presented.

At most of the meetings the papers were illustrated either by lantern slides or by experiments, or both.

Respectfully submitted,

JAMES S. ROGERS,
Chairman.

PHILADELPHIA, January 10, 1912.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS.

PHILADELPHIA, PA., January, 1911.

To the President and Members of the Franklin Institute:

The Committee on Science and the Arts has the honor to submit the following account of its operation for the year ending September 30, 1911:

The total number of applications for investigation pending September 30, 1911, was 58; cases added during the year, 6; cases closed, 44; cases pending September 30, 1911, 20.

In six of the cases considered the award of the John Scott Legacy Medal and Premium was recommended (five awards were made and protest against one is pending); in five cases the award of the Edward Longstreth Medal of Merit was recommended (three awards were made, one was changed to a Certificate of Merit, and one is being protested); two Certificates of Merit were recommended and awarded; fourteen reports were made advisory, and seventeen cases were dismissed.

On the recommendation of the Special Committee on the awarding of the Elliott Cresson Medal in recognition of leading and directive work in science and the arts, seven awards were made.

On the recommendation of the Subcommittee on Literature, four Edward Longstreth Medals for "meritorious papers" and one Howard N. Potts Medal for "papers of especial merit" published in the JOURNAL were awarded.

A list of the above awards is appended hereto.

Amendments relating to the 1909 Regulations were considered and adopted in their final form. Amongst these was the resolution defining the duty of the Subcommittee on Literature to consider the merits of any publication or treatise devoted to Science and the Mechanic Arts, with a view to recommending the award of the Potts Medal once annually.

A resolution was made that the committee adopt the principle of recognizing the life-work of scientists and technologists of long-established reputation by according to such the highest awards of the Institute.

The preliminary report of the Special Committee on the Descriptive Pamphlet was adopted. This committee recommended the foundation of a "Franklin" Gold Medal to be awarded to those having an established reputation for leading work in physical science, etc., and defined the grades of the present awards.

The Chairman desires to express his deep appreciation of the active and efficient co-operation of his fellow-members of the committee.

Respectfully submitted,

GEORGE A. HOADLEY,
Chairman.

PHILADELPHIA, January 10, 1912.

APPENDIX.

Details of Awards.

The Elliott Cresson Medal to:

Edward Weston, D.Sc., LL.D., for distinguished leading and directive work in electrical discovery and in the advancement of electrical application.

Joseph John Thomson, Knight, D.Sc., LL.D., for distinguished leading and directive work in the advancement of our knowledge of the physical sciences.

Ernest Rutherford, Sc.D., LL.D., for distinguished leading and directive work in the advancement of our knowledge of electrical theory.

Harvey W. Wiley, Ph.D., LL.D., for distinguished leading and directive work in the field of agricultural and physiological chemistry.

John A. Brashear, Sc.D., LL.D., for distinguished leading and directive work in the production and perfection of instruments for astronomical research.

John Fritz for distinguished leading and directive work in the advancement of the iron and steel industries.

Robert A. Hadfield, Knight, for distinguished leading and directive work in the advancement of our knowledge of metallurgical science.

The Howard N. Potts Medal to:

W. W. Coblentz, Ph.D., for his paper on "The Reflecting Power of Metals."

The Edward Longstreth Medal of Merit to:

Charles A. Bennett for his Typewriter.

James A. P. Crisfield for his Apparatus for Determining Moisture in Fuels.

Charles F. Roper for his Safety Propeller.

Edward P. Hyde, Ph.D., for his paper on "The Physical Production of Light."

Joseph Samuel Hepburn, A.M., M.S., for his paper on "Recent Progress in the Chemistry of the Sugars."

Morton G. Lloyd, E.E., Ph.D., for his paper on "Magnetic Hysteresis."

Walter V. Turner for his paper on "The Air Brake as Related to Progress in Locomotives."

The Certificate of Merit to:

Robert N. Baylis for his Brush Holder for Dynamos.

Charles J. Branch for his Asbestos-Gleam Shades and Reflectors.

H. W. Hardinge for his Conical Pebble Mill.

The John Scott Legacy Medal and Premium to:

D. McFarlan Moore for the "Moore Light."

Axel Welin for his Quadrant Davit.

Albert F. Shore for his Scleroscope.

Edward Allen Colby for his Induction Electric Furnace.

Bernard Arthur Behrend for his High-Speed Electric Generators.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, January 3, 1912.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January, 3, 1912.

DR. GEORGE A. HOADLEY *in the Chair.*

The following report was presented for final action:

No. 2506.—Sherardizing Metallic Surfaces. Action deferred.

For first reading:

No. 2466.—Tantalum Wave—Detector.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—The stated meeting was held in the Hall of the Institute on Thursday, January 4, 1912, at 8 P.M., with Mr. Louis E. Levy in the chair. Seventy members and visitors were present. The minutes of the previous meeting were read and approved.

Mr. Henry A. Gardner, Assistant Director of the Institute of Industrial Research, Washington, D. C., delivered an address on "Some Industrial Research Problems of Public Importance," in the course of which he described the various researches conducted by the Institute of Industrial Research, including the manufacture of paints, the corrosion of iron and

of fence-wire, the use of tanks of Portland cement as containers for corrosive liquids; the canning of vegetables. The lecture was illustrated by means of lantern slides. The paper was discussed, a vote of thanks was extended to Mr. Gardner, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. MILTON KUTZ, 262 South Fifty-seventh St., Philadelphia.

NON-RESIDENT.

MR. WILFORD RENO, Otis Elevator Co., 17 Battery Place, New York City.
MR. ANGUS SINCLAIR, 114 Liberty St., New York City.

Changes of Address.

PROF. GEORGE FORBES, 11 Little College St., Westminster S. W., London.
MR. J. MCGOWAN, JR., The Robeson, Camden, N. J.
SIR ROBERT A. HADFIELD, 22 Carlton House Terrace, London, S. W., England.
MR. HAROLD C. HEILMAN, 110 Harvey St., Philadelphia.
MR. T. BROOM BELFIELD, 2841 Diamond St., Philadelphia.
MR. H. CLYDE SNOOK, 1210 Race St., Philadelphia.
MR. A. G. PETERKIN, JR., 1653 Pratt St., Frankford, Philadelphia.
MR. C. L. MATTHEWS, 503 Carpenter St., Germantown, Philadelphia.
MR. CALVIN F. CROWELL, 113 North Front St., Philadelphia.
MR. SAMUEL M. FELTON, 1121 Peoples Gas Building, Chicago, Ill.
MR. J. STANFORD BROWN, Farview P. O., Black Hall, Conn.
MR. GEORGE R. WOOD, Arcade Building, Philadelphia.
MR. DANIEL M. LUEHRS, 282 Park View Ave., Detroit, Mich.
MR. GEORGE C. REESE, Darby, Delaware Co., Pa.

NECROLOGY.

Mr. R. H. Krischker, 5100 Hazel Avenue, Philadelphia, died at Wildwood Crest, N. J. Mr. Krischker was born in Glogau, Silesia, Germany.

When quite a youth he was apprenticed to a watchmaker, studying this trade as well as that of jeweller and optician. When fifteen years of age he came to the United States, and in the course of a few years opened a place of business at 145 North Ninth Street, Philadelphia, where he continued for twenty-nine years.

He retired from active business about nine years ago. A widow survives him.

His connection with the Institute dates from October 23, 1894, when he became a life member.

LIBRARY NOTES.

Purchases.

Who's Who. An annual biographical dictionary, 1910.
MARBURG, E.—Framed Structures and Girders. Vol. I.
GERHARD, W. P.—The Sanitation, Water Supply, and Sewage Disposal of Country Houses.
EMERSON, H.—Twelve Principles of Efficiency.
Minerva, Jahrbuch der Gelehrten Welt. Vol. 21. 1911–1912.
RAFFY, L.—Leçons sur les Applications géométriques de L'analyse.
GOURSAT, E.—Cours D'analyse mathematique. 2 volumes.
Œuvres de Pierre Curie.
Hütte, des ingenieurs taschenbuch. 3 volumes. 21st edition.
BILES, J. H.—The Design and Construction of Ships. 2 volumes.
MCDERMAID, N. J.—Shipyard Practice as Applied to Warship Construction.
TAYLOR, D. W.—The Speed and Power of Ships. 2 volumes.
FOUCAULT, L.—Recueil des travux scientifiques. 2 volumes.
BAUER, G., and O. LASCHE.—Marine Steam Turbines.
HALLWACHS, W., and others, editors.—Gesammelte Abhandlungen von F. Kohlrausch. 2 volumes.
LANE, M.—Das Relativitätsprinzip.
HEFTER, G.—Technologie der Fette und Oele. Vol. 3.
HUEBL, A. F. VON.—Die photographischen Lichtfilter.
RAFTER, G. W., and M. M. BAKER.—Sewage Disposal in the United States.
Autobiography of John Fritz.

Gifts.

Baladaque da Silva, A. A.—Le Probleme de la Vie. Lisbon, 1911. (From the Author.)
U. S. Commissioner of Internal Revenue, Annual Report for 1911. Washington, 1911. (From the Commissioner.)
American Mining Congress, Report of the Proceedings, 14th Annual Session, October 24–28, 1911, Chicago, Ill. Denver, 1911. (From the Congress.)
Staffordshire Iron and Steel Institute, Proceedings. Vol. 26, Session, 1910–11. Stourbridge, 1911. (From the Institute.)
Massachusetts State Board of Health, Annual Report, 1910. Boston, 1911. (From the State Board.)
Canada Department of Customs, Report for year ended March, 1911. Ottawa, 1911. (From the Department.)
Australia Bureau of Census and Statistics—Shipping and Oversea Migration for 1910, Trade and Customs and Excise Revenue for 1910. Melbourne, 1911. (From the Bureau.)
Pennsylvania Water Supply Commission, Annual Report, 1910. Harrisburg, 1911. (From Mr. John Birkinbine.)
Lake Superior Mining Institute, Proceedings of the 16th Annual Meeting, August 22–24, 1911. Ishpeming, 1911. (From the Institute.)

Smithsonian Institution, Annual Report for 1910. Washington, D. C., 1911. (From the Institution.)

Railway Signal Association, Proceedings of the Annual Convention, October, 10–12, 1911. Bethlehem, 1911. (From the Association.)

American Railway Master Mechanics' Association, Proceedings of the 44th Annual Convention, June 14–16, 1911. Chicago, 1911. (From the Association.)

Iowa Railroad Commissioners, 33d Annual Report for 1910. Des Moines, 1910. (From the Commissioner.)

New York Public Service Commission, Proceedings, Vol. 5, 1910. No place, no date. (From the Commission.)

Fritz, John, Autobiography. New York, 1912. (From the Author.)

Institution of Civil Engineers, Minutes of Proceedings, Vol. 186, 1910–11, Part 4. London, 1911. (From the Institution.)

Memorial Addresses on the Life and Character of Joel Cook, delivered in the House of Representatives, January 22, 1911, and the Senate, December 15, 1910. Washington, 1911. (From Hon. J. Hampton Moore.)

Association Francaise pour L'Advancement des Sciences, Compte Rendu de la 39 Session, Toulouse, 1910. Paris, 1911. (From the Association.)

Reale Instituto d'Incoraggiamento di Napoli, Atti del, 1910. Vol. 52. Napoli, 1911. (From the Institute.)

Harvard University, Catalogue 1911–12. Cambridge, 1911. (From the University.)

Canal Record, Vols. 1 to 4, September 4, 1907, to August 23, 1911. Ancon, 1908–1911. (From the Secretary of the Isthmian Canal Commission.)

U. S. Navy Department, Report of the Secretary of the Navy for 1911. Washington, 1911. (From the Department.)

Memorial Addresses on the Life and Character of Wm. W. Foulkrod, delivered in the House of Representatives, January 22, 1911, and in the Senate, December 6, 1910. Washington, 1911. (From Hon. J. Hampton Moore.)

CORRESPONDENCE.

ROSE POLYTECHNIC INSTITUTE, DEPARTMENT OF CHEMICAL ENGINEERING.

John White, Director. TERRE HAUTE, IND., December 22, 1911.

THE DETERMINATION OF MOISTURE IN FUELS.

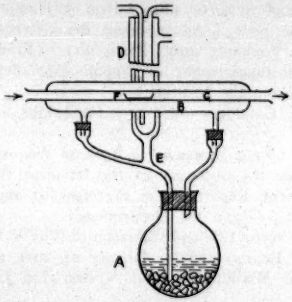
To the Editor JOURNAL OF THE FRANKLIN INSTITUTE,
Philadelphia, Pa.

DEAR SIR:

In the November number of the JOURNAL OF THE FRANKLIN INSTITUTE, Page 495, there appeared an article by J. A. P. Crisfield, bearing the above title, in which the author describes his "Moisture Determinator," designed for use in determining the moisture in fuels.

The principles upon which the construction and action of Mr. Crisfield's "Determinator" are based are similar to those which we have made use of for the past two years in this laboratory, and which were described by us in a paper read before the Division of Industrial Chemists and Chemical Engineers at the Minneapolis meeting of the American Chemical Society in 1910. The paper has never been published, and a brief description of the apparatus and method is given below.

The apparatus is illustrated in the accompanying figure, and was adapted from that described by Delbridge (*American Chemical Journal*, 41, 403, 1909). In the figure, *A*, the boiling flask, is a wide-mouth flask of about 500 C.c. capacity, carrying a two-hole stopper, through which it is connected, as shown, with a reflux condenser *D* and with the drying apparatus *B*. This consists of a simple form of condenser, with the two side tubes on the same side of the jacket. The inner tube *C* should be about 20 mm.



wide and approximately 350 mm. in length, and should not project beyond the jacket more than 5 cm. at the ends.

To carry out the determination, a weighted sample of material, contained in a boat *F* of suitable size (we use one of aluminum or porcelain), is placed in the inner tube *C*. Flask *A*, which should contain some pieces of pumice or broken porcelain to aid the boiling, is half filled with a suitable boiling liquid (for fuels we use xylene), the vapors of which pass through the jacket surrounding the tube containing the fuel, thence into the reflux condenser, where they are condensed and run back into the flask. For fuels we pass through the tube C a *dry*, non-oxidizing atmosphere, such as carbon dioxide or nitrogen, the direction of passage being indicated by the arrows.

The moisture can be determined either by absorption in a suitable drying agent, or by loss of weight. We have demonstrated that, at the temperature used, 140°C., the loss of volatile matter is negligible.

Remarkably concordant results can easily be obtained with the apparatus, provided that the fuel is crushed to a suitable size, one-eighth inch or less.

Using xylene the time required for a determination is from twenty to thirty minutes, and if the estimation of the moisture is made by the loss in weight several boats can be placed in the apparatus at once, thus still further reducing the time of a determination.

Regarding the importance of a correct determination of the moisture in fuels, and the difficulties attached thereto, as pointed out by Mr. Crisfield, there can be no difference in opinion. It is equally certain that the old laboratory method, as recommended by the committee of the American Chemical Society in 1899, for a variety of reasons, does not yield correct results, being invariably too low. Hence the need of better apparatus for such determinations.

Signed,

JOHN WHITE.

BOOK NOTICES.

PHOTOGRAMS OF THE YEAR 1911–12. Typical photographic pictures of the year reproduced and criticised. Edited by H. Snowden Ward, F.R.P.S. 154 pages; about 100 illustrations; 7 x 10 inches. Paper covers, $1.25; cloth, gilt, $1.75. American agents, Tennant & Ward, New York.

The present volume shows considerable changes over past issues of the series. The text, as always, is made up of an extended, descriptive critique, by the editor, of the pictures reproduced. This critique gives a survey of pictures with helpful criticism designed to broaden the outlook of the pictorial worker and aid him in his picture-making with the camera. The pictures criticised represent a variety of schools, and comprise examples of the work of most of the leading pictorialists through Europe and America. On other pages the progress of pictorial photography in France, South Africa, Germany, and Australia is summarized by well-known pictorial workers in those countries.

The number of pictures reproduced is somewhat smaller than in past years. This change, it is stated, was made in order to give full-page illustrations in every case, as more satisfactory alike to photographers and readers. The illustrations are printed in black-and-white and in sepia, some illustrations in three colors reproduced from autochromes, and a hand-made photogravure frontispiece by J. Craig Annan. The quality of the reproductions and printing is unusually good.

PUBLICATIONS RECEIVED.

Photograms of the Year. Typical photographic pictures reproduced and criticised, edited by H. Snowden Ward, F.R.P.S. 1911–1912. 154 pages, illustrations, plates, quarto. London, George Routledge & Sons; New York, Tennant & Ward. Price, in paper, $1.25.

Penrose's Pictorial Annual. The Process year book, edited by William

Gamble, 1911–1912, vol. 17. 224 pages, illustrations, portraits, plates, quarto. London, Penrose & Co.; New York, Tennant & Ward. Price, cloth, $2.50.

United States Geological Survey. Mineral products of the United States calendars years 1901 to 1910 (sheet). Washington, U. S. Government, 1911.

Cocoa and Chocolate: Their chemistry and manufacture, by R. Whymper. 327 pages, illustrations, plates, quarto. Philadelphia, P. Blakiston's Son & Co., 1912. Price, in cloth, $5 net.

Photography Outdoors. Practical suggestions in simple language, telling the beginner about the equipment required, the choice and treatment of many kinds of subjects, and how to make pictures. 64 pages, 12mo. New York, Tennant & Ward, n. d. Price, in paper, 25 cents.

Photography at Home. A Handbook to the Use of the Camera in the Home for Pleasure and Profit; with working methods and reliable formulæ. 64 pages, 12mo. New York, Tennant & Ward, n. d. Price, in paper, 25 cents.

FRANKLIN INSTITUTE'S GOOD YEAR.

FEW American institutions have been of greater service in developing the material growth and prosperity of the American people than the Franklin Institute in this city, although its merits are seldom appreciated. It has stimulated and otherwise encouraged invention in a most practical manner. Its medals are among the most desired of all rewards which an inventor may achieve, because they are based on originality and service to mankind.

For many years the institution was so neglected that a few men kept it going to prevent at least a curtailment of its many efficiencies. Now it has passed into the prosperous stage, and in the last year it has received additional bequests, so that the long-cherished project of a new building on the Parkway seems certain of achievement in the near future. Not only is the building fund constantly growing larger, but the maintenance fund is increasing. Perhaps nowhere in the world will be found such a library, such a school, or such other opportunities for the study of applied mechanics.

Some one has said that a study of the newspapers published in the whole world in the last half of the eighteenth century disclosed that Franklin's name was mentioned more times than that of any other individual. This is a notable tribute to the versatility of the great Philadelphian. His claims to public gratitude are numberless, but certainly the institute which bears his name and which is his legitimate child is one of the things which we ought to be proud of, because it is continuing that creative work which Franklin himself ever stimulated. As this city owes much of its prosperity to the progress of invention, it may fairly be assumed that when the time comes to begin actual construction there will be no lack of funds to make the new building commensurate with the needs of the institution and, as well, an ornament to the Parkway.—Editorial, *Philadelphia Inquirer,* January 22, 1912.

CURRENT TOPICS

Diamonds at High Temperatures. ANON. (*Eng.*, xcii, 2381, 236.)—Cornelio Doelter, who has been investigating the electrolytic or electronic conductivity of solids, salts, and minerals, etc., has determined the conductivity of diamonds between 880°C. and 1290°C. in an atmosphere of hydrogen or of nitrogen. The specimen was a plate 1 square centimetre in area and 1 millimetre in thickness. The resistance was 58,800 ohms at 950°C., but fell to 370 ohms at 1220°C., it rose to 930 ohms at 1260°C., and fell once more to 590 ohms at the maximum temperature applied, 1290°C. Similar phenomena had been observed in quartz, and they are not suggestive of a really uniform substance; in the case of quartz some electrolytic effect would be possible. In other experiments, Doelter heated diamonds in hydrogen, nitrogen, chlorine, and carbon dioxide up to 1550°C. and failed to observe any conversion of diamond into graphite; there was some brownish-black discoloration, probably due to amorphous carbon, but no formation of graphite, as has been often assumed.

Mixtures of Cement and Hydraulic Materials for Floors of Wet Cellars. SCHÄCKE. (*Allgem. Zeits. fur Bierbrauerie und Malzfabrik*, xxxix, 499.)—Cement is unsuitable for floors of cellars which are exposed to the saline or acid liquors of beer and yeast residues. Asphalt and similar mastics also fail to withstand this action. It is found that a mixture of cement, trass, and sand is suitable; but a cheaper material is recommended, composed of 1 part of cement, 2 of sand, and 2 of leucitophyr, a phonolite which appears commercially as artificial potash fertilizer at a price of 2 M. per 75 kilos. (50c per 165 pounds). It contains 17.5 per cent. of alkalies, as compared to 10.5 per cent. in trass.

Nickel-Zinc Alloys. E. VIGOUROUX and A. BOURBON. (*Bull. Soc. Chim.*, ix, 873.)—Besides the compound, $NiZn_3$, already known, two new compounds of nickel and zinc are shown to exist, viz.: $NiZn_4$ and Ni_3Zn. The $NiZn_4$ compound has been isolated as a crystalline, non-magnetic powder, with a specific gravity of 7.71. Its melting point is about 850°C.

Prohibition of the Importing of Chemicals for the Production of Explosives into Turkey. ANON. (*Board of Trade J.*, Nov. 2, 1911.)—The prohibition will apply to the following articles: potassium chlorate, sodium chlorate, potassium nitrate, sodium

nitrate, picrates, nitroglycerin, guncotton; but if these articles are destined for industrial or agricultural uses, they will be delivered to the consignees, with the authorization of the *"Grand Maîtrise d'Artillerie,"* in quantities which will be fixed prior to importation for each importer, by the Ministers of Public Works and Agriculture, respectively.

On the Metallography of the Selenium-Antimony Systems. H. PÉLABON. (*Mon. Sci.*, 839, 767.)—The microscope examination of selenium-antimony mixtures leads to the following conclusions, which are analogous to those deduced from the determination of their curves of fusibility: (1) For certain proportions of the two constituents, the liquid mixture can be produced in two phases of closely approximating densities; (2) the only compound that can be obtained by direct fusion of the elements is the selenide Sb_2Se_3.

Salt Deposits of Ontario. ANON. (*Board of Trade J.*, Nov. 2, 1911. From the annual report of the Provincial Bureau of Mines.)—Salt is known to occur in that part of Ontario which lies entirely in the southwestern peninsula bordering Lake Huron, the St. Clair River, Lake St. Clair, and the Detroit River. Such exploratory boring as has been done indicates that there are a number of separate relatively small basins. The beds range from mere seams to formations 200 feet or more in thickness. The supply of salt in Ontario is practically inexhaustible. The bulk of the salt manufactured is used in Ontario. The quantity of salt produced in 1910 was 84,071 tons, valued at $414,978, as compared with 77,490 tons, valued at $389,573, in 1909.

Proposed United States Experimental Ore-Testing Station. ANON. (*Eng. and Mining World*, Nov. 4, 1911.)—The American Mining Congress has sent a memorial to the United States Congress asking for the establishment, under the direction of the Bureau of Mines, of a metallurgical experimental ore-testing station, where methods for extracting metal from low-grade ores can be devised and tested.

Upon the Mass of Gaseous Ions. W. DUANE. (*Mon. Sci.*, 839, 766.)—There is a great difference in the effects of the magnetic field on the positive and the negative current of the ions. No effect of the magnetic field, even up to 2,800 gauss, has been observed on the positive ions in the atmosphere, when the electric field was above 25 volts per centimetre. These results can be explained by admitting that the negative ions at low pressure are, to a great extent, produced by the atoms of hydrogen and the molecules of nitrogen (or of oxygen) in the air, and in hydrogen charged with

one or two elementary charges. The fact that the positive currents are not completely suppressed by the magnetic field indicates either that their free course is not sufficiently long or that it consists entirely of large ions. The fact that the negative current is sensibly suppressed by a weak magnetic field indicates that negative ions of molecular dimensions exist only at low pressure; that is to say, that negative ions are not created by the division of the molecules by the removal of the positive ions. The fact that under the influence of a magnetic field of 25 volts per centimetre this magnetic field constantly diminishes the positive current in hydrogen, but not in air, indicates that the positive ions in hydrogen are much smaller than those in air, and that the air does not contain a sensible quantity of positive ions of the same order of greatness (size) as the particles or ions of hydrogen, but very much smaller. These conclusions are opposed to the hypothesis of the existence of positive electrons under the conditions of these experiments.

The "Chromoscope." L. ARONS. (*Electro-techn. Zeit.*, xxxii, 729.)—This apparatus is intended for analyzing and reproducing the tints of colored surfaces and comparing different illuminants. The light from the surface under examination is caused to pass through a pair of Nicol prisms, which can change its intensity, and subsequently to illuminate the annulus of a Lummer-Brodhun prism. The light from the other source, such as daylight, illuminates the centre of the field, the color being adjustable by another pair of Nicols and a quartz plate of any desired thickness. The observer looks through the eye-piece and secures a balance of both color and brightness and observes the amount of rotation of the analyzers necessary to attain this condition. In this way a wide variety of tints can be produced. It is suggested that the mixed colors produced in this arrangement are desirable from a practical standpoint, as only tints of this character are met with under ordinary conditions.

Boiler Control: the Most Economical Amount of CO_2. A. BEMENT. (*Power*, xxxiv, 439.)—The highest efficiency in steam generation is always indicated by the highest CO_2. If it is not, there is some counteracting influence at work, because the higher the CO_2 the higher the temperature of combustion, and the higher the temperature the greater the efficiency. In many furnaces and with many methods of firing there is often a more or less serious loss of undeveloped heat in hydrocarbons which escape unburned. In a furnace of perfect mixing capacity the theoretical CO_2 may be realized. Neither high CO_2 nor complete combustion is attainable with irregular firing or bad stoker action. The chief difficulty is that the only feature to which much attention has been paid is the significance of CO_2 in its relation to excessive air supply. The other

feature, almost equally important, excessive or irregular fuel supply, is neither understood nor properly appreciated. There are four guiding principles in the use of CO_2 determinations: (1) If CO_2 increases after the supply of fuel, or the reduction of draught, it shows that there has been an excess of air. (2) If CO_2 falls after the supply of fuel, it shows incomplete combustion. (3) If the percentage of CO_2 is irregular, it indicates an irregular condition of combustion. (4) Assuming constant or uniform conditions of combustion, it is an indication of a deficiency of the furnace in its power to secure a good mixture of the gases, if it is impossible to realize a high CO_2 content.

Mill Lighting. G. H. STICKNEY. (*Amer. Ill. Engin. Soc. Trans.*, vi, 478.)—This article opens with general remarks on the quality of illumination best suited for paper mills, textile and steel works, etc. For general illumination an intensity of ¾ to 2 candle-feet is advised, for fine work in machine shops 3 to 6, for spinning and carding rooms 1 to 4. Lamps should be properly placed with regard to tools so as to avoid inconvenient shadows. Various forms of steel reflectors with enamelled or matte surfaces are recommended. Reference is made to the bearing of illumination on accident, the benefit of local, adjustable lamps for special work, and the need for an illuminant which approaches daylight fairly closely in spectral composition.

Photo-electric Potassium Cells. J. ELSTER and H. GEITEL. (*Phys. Zeitschr.*, xii, 609.)—The photo-effect in alkali metals may be increased by making them the cathode in a glow discharge through low-pressure hydrogen. The metals are then colored green or blue, except sodium, which becomes brown. The cells so prepared show a gradual increase in the vacuum and the color fades. The fading is apparently due to the production of a colorless hydride, which also accounts for the absorption of the hydrogen. Cells of greater permanency, suitable for photometry, may be obtained by filling them with argon or helium. (Detailed instructions are given on this procedure.) A glow discharge through these gases does not color the alkali metals.

Diminution in the Intensity of the Ultra-violet Rays From Quartz-tube Mercury Lamps. J. COURMONT and C. NOGIER. (*Comptes Rend.*, clii, 1746.)—Quartz-tube mercury vapor lamps, working at a high temperature, give a spectrum very rich in ultra-violet rays. But this notably diminishes with time. Spectrometric investigations show that after a few months the spectrum is less intense, and the chemical action on potassium ferrocyanide paper, the power of destroying bacteria, and the influence on the skin become less marked. This decrease in power appears to be

due to the gradual production of a gray deposit on the inside of the tube, which is possibly mercury silicate. Or it may be due to a change in the gaseous composition in the tube. Observation suggests that it is mainly due to the high temperature, and that it might be beneficial to cool the lamps while in action.

Development of Photographic Images After Fixing. A. and L. LUMIÈRE and A. SEYEWETZ. (*Comptes Rend.*, clvii, 102.)—Neuhauss has shown that it is possible to develop the latent photographic images upon gelatino-silver bromide plates, after these have been fixed in sodium hyposulphite. It is, however, only when the plate has been exposed twenty times the normal time required by ordinary development methods that his method can be employed. It is shown that a two per cent. solution of sodium hyposulphite is the best bath for fixing. When this bath is used slow plates only need four times and rapid plates six times the normal exposure. The double silver-sodium sulphite gives the best results as a developer. It was attempted to replace the silver salts by other metals whose sulphites are soluble in an excess of sodium sulphite. Mercury alone gives interesting results. Under certain conditions mercury salts are preferable to silver salts, because they give less dichroic and more opaque images.

Internal Pressure of Gases, and Law of Molecular Attraction. A. LEDUC. (*Comptes Rend.*, cliii, 179.)—Calculating from established formulas, it is shown that the internal pressure of SO_2 diminishes with rise of temperature, rendering the equations of Van der Waals, Clausius, and Sarrau incorrect. At corresponding temperatures, and for gases of the same molecular construction, the mutual attraction between two molecules of the same gas is found to be proportional to the square of their mass, and inversely proportional to the fourth power of their distance apart.

To Etch Names, Figures, etc., on Steel. E. (*Elektrochem. Zeit.*, xviii, 145.)—The surface is first covered with a carefully-prepared mixture of two parts of powdered asphalt, one part rosin, one and one-half parts wax, and a little tallow. Of this a very thin coating is put on the surface to be etched, and after inscribing the design the etching is done by nitric acid, acetic acid, or tartaric acid.

The Cedford Gas Process. E. ERDMANN. (*J. Gasbeleucht.*, liv, 737.)—This is the production of methane from carbon monoxide and hydrogen on a commercial scale. Carefully purified, dry water-gas, free from carbon dioxide, is treated in a special Linde apparatus. Here it is separated into a gas rich in carbon monoxide, and one containing only 17 per cent. carbon monoxide and 81 per cent. hydrogen. This latter gas is passed over a catalytic mass of pumice

stone covered with nickel, and heated to 300°C. When the temperature is below 300°C. and the content of carbon monoxide below 17 per cent. the carbon monoxide is changed quantitatively into methane. When the temperature is too high, carbon dioxide is formed, and when the content of carbon monoxide is too great, carbon is deposited. The first gas, rich in carbon monoxide, is used for fuel. The chief advantages are: (1) the poisonous carbon monoxide is removed, making the gas much safer; (2) the heat value is increased from 2800 to 8500 calories. The costs of the process are given.

Theories of Solution. JAS. WALKER. (*Chem. News*, civ, 104.)—The author considers especially the case of strong electrolytes and presents strong evidence in favor of the view that their abnormal behavior is to be attributed to the non-ionized portion rather than to the ions. He says: "To put the matter briefly, in the equilibrium between electrolytes agreement will be obtained between theory and experiment whether we use the mass-action law or an empirical law such as Van't Hoff's dilution formula, provided only that we attribute the abnormality to the non-ionized portion of the electrolyte. Thus we can deduce the ordinary formulas for hydrolysis, or for isohydric solutions, as readily for abnormal as for normal electrolytes, and find the most satisfactory agreement with experiment in both cases"

Tool Steel Direct From the Ore. A. STANSFIELD. (*J. Can. Min. Inst.*, xiii, 151.)—Experiments were made upon the direct production of steel from magnetite ores containing titanium and traces of vanadium, in a cylindrical furnace 18 inches high and 14 inches in diameter, with two lateral, graphite electrodes 1 inch square. The maximum power used was 200 ampères at 110 volts. The slag and ore were first fused by an arc between the electrodes, then the electrodes were dipped in the bath. The ore contained 51.45 per cent. iron, 7.5 per cent. titanium, 0.12 per cent. nickel, and traces of vanadium and sulphur. The charge was 100 parts ore, 20 of limestone, and 18 of carbon formed into briquettes with molasses and water in the proportion of 10:16. No ferromanganese or other deoxidizing agent was used before tapping, and sound ingots, three pounds in weight, were obtained. This could not be done with non-titaniferous ore. The metal was tool steel of good quality. The total cost of ore, coal, limestone, power, and electrodes is estimated at 2 cents per 1 pound of steel.

Simultaneous Exposure and Development. O. MENTE. (*Atèlier Phot.*, xviii, 66.)—This process is particularly successful for copying hard negatives on bromide paper. The paper is wetted with 10 cubic centimetres rodinal, 20 cubic centimetres glycerol, and

40 cubic centimetres water, and exposed in the copying camera while wet for a time long enough to print the shadows of the picture. An orange glass is then placed before the lens, which, with a sheet of ground glass to diffuse the light, enables the development to be observed. When the shadows are sufficiently dense, the glasses are removed and an additional exposure given for the high lights; this does not overexpose the shadows, because the already developed silver image there screens the silver bromide beneath.

Utilization of the Peat Bogs of Canada. ANON. (*Elec. Rev. West. Elect.*, lix, 549.)—The peat bogs of Canada are estimated to cover about 36,000 square miles, and are capable of producing 28,000,000,000 tons of air-dried peat, equal in value as fuel to 14,000,000,000 tons of coal. A well-equipped plant at Ottawa for producing air-dried peat is described.

Influence of Light on the Conductivity of Thin Sheets of Gold and Silver. S. PIENKOWSKI. (*Bull. Acad. Roy. Belg.*, 1911, 603.)—Light has no influence on the conductivity of transparent deposits of gold and silver on glass. Similar negative results were likewise obtained with the identical gold layer used by Bronislavski, who states that white light doubles the conductivity of the deposits, and blue light increases it 75 per cent.

Aluminum Versus Copper. C. H. PALMER. (*Elec. Rev. West. Elect.*, lix, 523.)—Considering several 3,000 volts transmission lines using aluminum instead of copper, it is shown that hard drawn aluminum and copper wires will have the same conductivity if the former has 1.64 times the sectional area, and therefore 1.28 times the diameter, of the latter. By using aluminum, 25 per cent. on the total cost of a transmission line can be saved.

The Intensity of the Ultra-violet Light Emitted by an Electrical Discharge at Low Pressures. E. W. B. GILL. (*Phil. Mag.*, xxii, 412.)—A discharge was produced in air contained in a quartz tube between aluminum electrodes 7.5 centimetres apart. The intensity of the light proceeding from different parts of the discharge was estimated by the rate at which a zinc plate lost its charge. For pressures exceeding that corresponding to the minimum spark potential, the maximum intensity of light is near the anode; for pressures less than this, it is near the cathode.

The Molecular Weight of Thorium Emanation. MAY. S. LESLIE. (*Compt. Rend.*, cliii, 328.)—The apparatus devised by Debierne for determining the molecular weight of RaEm by diffusion through a small opening was used by the author, slightly

modified, to determine the molecular weight of the ThEm. After a number of experiments, in which the rate of diffusion of the ThEm was compared with that of oxygen, it was found that the ThEm's molecular weight was approximately 200.

The Anti-cathodes of X-Ray Tubes. J. SCHOFIELD. (*Nature*, lxxxvii, 215.)—An X-ray tube fitted with an anti-cathode of carborundum worked very successfully. It did not pass into the hard condition so readily as tubes fitted with other more expensive materials, such as platinum, tantalum, etc.

Flame Arising From the Nitrogen-burning Arc. R. J. STRUTT. (*Proc. Royal Socy.*, lxxxv*a*, 533.)—Recent investigations have thrown considerable light on the processes occurring in the nitrogen-burning arc, which do not agree with the conclusions arrived at by other investigators. In pure gases there is no flame, though the form of the arc from a Ruhmkorff coil, supplied with alternating current in the primary circuit, varies in form with the gas employed. With air, there is an arc with a slight rise in the middle, accompanied by a greenish-yellow envelope, which rises to a considerable height above the arc, and terminates in a sharp point like a candle flame. On reduction of pressure this flame expands until it fills the bulb containing the air. It remains visible for a moment after the arc has been switched off. This greenish-yellow flame is in no way distinct from the "after-glow" observed in vacuum tubes containing air. The latter can, by suitable experimental analysis, be proved to be due to the further oxidation of oxides of nitrogen by ozone. Accordingly it is concluded that the flame arising from the arc is due to the same cause. The arc produces ozone and oxides of nitrogen. These substances produced independently unite chemically in the region above and beyond it.

Synthetic Sapphire. A. V. L. VERNEUIL. (*U. S. Patent* 1,004,505, 1911.)—A synthetic sapphire containing aluminum, iron and titanium oxides, and having the same color, transparency, and hardness (about 9, diamond being 10) as the natural sapphire, but distinguishable from the latter by having beneath its surface, and imbedded in it, a number of bubble-like spots bounded by rounded walls, and also curved, rift-like streaks or cracks. The body portion may also contain curved layers.

Novel Method for Removing Rust From Iron and Steel. H. JACOB and R. KAESBOHRER. (*Chem. Zeit.*, xxxv, 1911.)—The iron or steel from which the rust is to be removed is made the cathode in a solution of sodium sulphate in water, containing from 0.25 to 5.00 per cent. Carbon plates are used for the anode. The hydrogen gas evolved at the cathode reduces the rust so that it may

be brushed off, or removes it entirely. A weak current is used and the article allowed to remain over night in the solution. It is stated that the removal of rust is so complete, and the iron or steel so free from attack, that the method may be employed for its accurate determination.

Liming of Coal in Gas Manufacture. J. PATERSON. (*J. Gas Lighting*, cxvi, 449.)—A modification of Cooper's process of introducing lime with the coal into the retorts was adopted at Cheltenham with good results. The method used is to feed the quicklime on to the coal in the breaker by means of a hopper closed at the bottom by a roller and flexible shoot. A tapping device is provided to keep the lime flowing freely. The roller is driven by gearing from the shaft of the elevator, so that the lime and coal are used in constant proportions. A little steam is admitted under the rollers of the breaker and also into the overhead hoppers in the retort house to prevent dust, and the surface of the coal becomes uniformly coated with an adhering layer of lime. The coal used is a mixture of half South Yorkshire and half Derbyshire coal. During the first five months the quantity of lime used was 2.01 per cent. of the coal carbonized. The quantity of the sulphur compounds in the gas was reduced from 40 to 21.5 grains per cubic foot; the yield of gas increased by 829 cubic feet per ton over the average of the preceding three years; the yield of ammonium sulphate increased by 1.88 pounds per ton of coal over the average of the preceding seven years; the yield of tar decreased by 0.9 gallon per ton; and the illuminating power of the gas and the quality of the coke were not impaired. During the next six months, the improvement was maintained and the yield of gas further increased by 162 cubic feet per ton. The pull in the exhauster house was reduced from 0.11 inch to about half that amount, and a higher carbonizing temperature was attained. Trouble with stopped ascension pipes entirely ceased, except in the case of one retort which was charged by hand with unlimed coal.

Fur Dyeing. E. SCHLOTTHAUER. (*Farber Zeit.*, xxii, 397.)—In modern fur dyeing there are four different classes of work to be dealt with. (1) For dyeing solid shades, chiefly blacks, such as are required on Persians or Broadtails, the entire skin in immersed in the dye bath. For the two kinds of skins named, the logwood-tannin process is used, for dyeing blacks; for hareskins and Thibets, a logwood turmeric black is used. (2) If the hair is required to be of a different shade from the skin itself, the entire skin is first dyed by the immersion process, and a different dye solution is then applied to the hair by the brushing process. (3) If only the hair is to be dyed, the color is brushed on. (4) It is often desired to deepen the shade of the extreme tips of the surface hairs. Before

dyeing the furs have to be scoured by treating them with dilute caustic soda, or with lime water to which soda ash has been added. The actual dyeing process is made difficult by the extreme care which is necessary to prevent deterioration of the skin. Before reaching the dyer the furs are submitted to one of several preparing processes, of which the alum, chrome, sulphuric acid and sodium chloride, the chamois preparations, and the *"Schrotzurichtung"* are the most important. It is found that skins which have undergone the sulphuric acid and sodium chloride treatment have the least resistance to the shrivelling effect of the hot dye liquor, and chamois prepared skins have the most resistance. Even with these last, however, the temperature of the dye bath should not exceed 45°C. (113°F.). The shrivelling effect of hot dye liquor can be decreased by previously treating the furs with formaldehyde. Thus a chamois prepared sable which was affected at 52°C (125.6°F.), after a three-hour treatment with 2 per cent. of a 30 per cent. formaldehyde solution, did not shrivel until 69°C. (156°F.) was reached.

Technical Applications of Zirconia. C. R. BÖHM. (*Chem. Zeit.*, XXXV, 1261.)—This opens with a short summary of the various technical purposes for which zirconium compounds have been used or may be used in the future. The extreme hardness of zirconium carbide makes it a good polisher and useful for cutting glass. Zirconia is a very good insulator, and, mixed with good conducting material, it is used for electrical heating purposes. The iridium bar in the Heraeus furnace is glazed to prevent disintegration, by repeatedly coating it with a solution of yttrium and thorium nitrates and then igniting it; it is suggested that, in view of the great heat resisting power of zirconia, it would be advantageous to substitute a suitable zirconium salt for the thorium nitrate used in this treatment. Pure zirconium oxide is a fine white powder, suitable for the manufacture of white paint.

Tungsten Production in the United States in 1911. COLORADO AND CALIFORNIA CHIEF PRODUCING STATES.—There was a sharp falling off in the production of tungsten ores in 1911, owing to the decrease in the market for tool steels, in which the bulk of the tungsten is used. According to preliminary figures collected by Frank L. Hess, of the United States Geological Survey, about 1,125 short tons of concentrates carrying 60 per cent. tungsten trioxide were produced and shipped during the year, which is less than two-thirds of the output for 1910, when 1821 tons were marketed. The prices for the year ranged from $4.50 to $8.50 per unit, depending on quantity, quality, and individual bargaining. At the close of the year $5.00 per unit was offered. The unit is twenty pounds of tungsten trioxide per short ton of ore.

As usual, the Boulder County (Colorado) field gave the largest

returns, 740 tons, and the Atolia (California) deposits the second largest. Smaller amounts were produced in Arizona, Nevada, Idaho, and Washington.

The ore mined in Boulder County is ferberite (iron tungstate), which is not obtained in large quantity at any other place in the world. In spite of the poor market several new companies were formed to mine ore in the Boulder field and commenced operations during the year. Two companies profitably worked over tailings left from former operations. A considerable quantity of the ore mined both in this and in other fields was not marketed.

The Atolia field did not make so large a production as in 1910, but carried on work through most of the year.

Near Nipton, Cal., work was done by several persons on tungsten-bearing veins, but most of the ore was left at the mines to await higher prices.

In Arizona a number of carloads of ore were mined near Arivaca, more than 70 miles south of Tucson, and hauled to that place for shipment to Denver for milling.

New mills for treating tungsten ores were operated at Osceola, Nev., and in the Blue Wing district on Patterson Creek, Idaho, and a new mill was being built at the close of the year at Round Mountain, Nev. Financial difficulties overtook the company operating at Osceola and the concerns in Washington, so that little was done at those places.

The tungsten ore in the Blue Wing district had been long mistaken for a dark zinc blende, with which it occurs.

New discoveries of wolframite were reported from the vicinity of Oroville, Wash., and in silver-bearing veins in the Sonoma Range, south of Golconda, Nev. Hübnerite was found in veins once worked for silver in the Potosi district, nine miles from Pony, Mont., and scheelite was found in gold veins in the New Goldfield district near Rebel Creek, Nev.

Tinning Iron. ROBT. GRIMSHAW. (*Met. Ind.*, ix, ii, 471.)—To insure a well-tinned surface for iron articles, it is advisable to copper them first. According to Claudius, the process is: about 30 pounds of the articles are placed in a tumbling barrel, into which is poured a mixture of 20 litres water, 1 kilogram sulphuric acid, and 20 grammes of tin salts. The articles are tumbled for fifteen minutes in this bath; the liquid run off and replaced by water; they are tumbled five minutes in the water, and the process repeated twice with fresh water. Then place in the tumbling barrel a copper solution, consisting of 50 grammes copper sulphate, 30 grammes zinc sulphate, and 20 litres water, made slightly acid with sulphuric acid; the articles are tumbled fifteen minutes in this. Then rinse with pure water and they will be well coppered, bright, and polished. It is better to tin them at once, without drying them.

The tin bath consists of a solution of three parts of cream of tartar and of tin salt in 20 litres of warm water. The smaller articles are laid on a perforated zinc plate and placed in the bath and moved about by a zinc rod. In from thirty minutes to an hour they will be found to be sufficiently tinned; they are then rinsed and dried. Larger articles are first pickled, then plated in a weak solution of copper sulphate and rinsed without letting the hands touch them, bound with a tin wire and hung in a tin bath, and left there till the tinning is complete.

Brown on Brass. ANON. (*Metal Industry*, ix, ii, 473.)—The following solution produces a number of different shades on brass, from a greenish tone, a gray light brown, dark brown, or black:

Potassium sulphide	½ ounce.
Water	1 gallon.

When cold this gives a gray or greenish color, at 100°F. a light brown to reddish brown, at 140°F. a dark brown, at 180°F. a black color.

The Society of Automobile Engineers.—The winter meeting of the above society was held in New York on January 18–20. The following were amongst the papers read at the meeting: "Efficiency of Compound Gas Engines," by Eugene P. Batzell. "Starters for Gas Engines," by J. W. Fitzgerald. "Motor and Transmission for Commercial Cars," by Eugene P. Batzell. "Automatic Spark Control," by Lon. R. Smith. "Balance of Automobile Motors," by Ernest R. Field. "Silent Chains," by Chester S. Ricker.

Several reports were presented by the Divisions of the Standards Committee of the society. This committee is actively engaged in the preparation of standards for all leading parts of machines and has already recommended sizes for such important details as motor truck parts, truck wheels, springs, ball and roller bearings, etc.

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